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Noni Cultivation and Production in Hawai'i

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Natural habitats

habitat (n.) The area or environment in which an organism or ecological community normally lives or occurs.

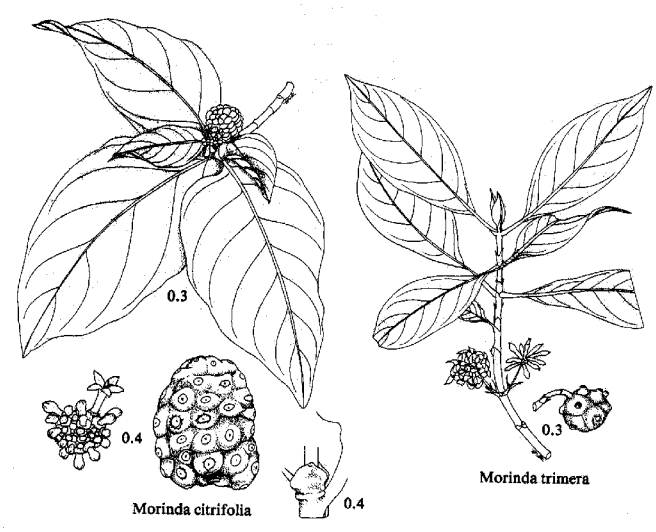
Noni (*Morinda citrifolia*) is believed to be among the original "canoe plants" that Hawaii's Polynesian colonizers brought with them in their voyaging canoes. The voyagers valued the plant for its medicine and dyes.

Since the early days of the colonizers noni has become naturalized on all the main Hawaiian islands. It grows naturally where it is relatively wet to moderately wet, from sea level to about 1500 feet elevation. It can be found near the coast, in open lowlands and grasslands, in gulches, as an early colonizing plant specie in recent lava flows, in disturbed forests of the dryer areas, such as the lowland forests in which hala (pandanus) and kukui nut (*Aleurites moluccana*) trees grow. It tolerates salinity and thrives within solution pits, or inland tide pools in which brackish water (ocean water mixed with fresh water) is found.

Two species of Morinda are recognized in Hawai'i, according to the Bishop Museum. *Morinda citrifolia* is referred to as Hawaiian noni. The other specie, *Morinda trimera*, is a relatively common forest understory plant on some Hawaiian islands. A variegated variety of *Morinda citrifolia* is also found in Hawai'i.

Lava flows

Noni is one of the first dicotyledenous plants to colonize low-elevation lava flows on the Big Island of Hawai'i. For example, young noni plants may be found growing from cracks in the 1980's-era lava flow near Kalapana in the Puna district of the Big Island. The lava flows hardened into a basaltic sheet several or more feet think at this location. Windswept noni plants bearing ripe fruit may be found growing in cracks in the lava. Noni seeds were presumably dropped into the cracks in the lava by birds, rodents or humans. Ancient Hawaiians seeded lava cracks with various kinds of drought-resistant plants or crops such as noni and coconut. As an aside, noni may also become established in cracks within asphalt or cement. Noni, ferns and grasses are some of the first plant species in Hawai'i to colonize lava flows. These plants may be found growing in the lava fields near Kailua-Kona, on the island of Hawai'i.



There are two *Morinda* species in Hawai'i, according to the Bishop Museum (reprinted with permission from Wagner, et al. (1999) *Manual of Flowering Plants of Hawai'i* (revised edition), University of Hawai'i Press).

Tidepools

Morinda citrifolia plants are quite salt tolerant and may be found thriving in Hawai'i's brackish (salty) tidepools and solution pits near the coast. For example, there is one location near Opihikao on the Big Island of Hawai'i where inland tide pools support a thriving population on noni plants. The salty, brackish water level at this location rises and subsides each day, according to the tides, filling up or emptying the tide pools. This particular tide pool is approximately 500 meters from shoreline. The brackish water rises up from beneath the ground every day at high tide. As the rising tide mixes with the fresh groundwater, a brackish mixture is created. In addition, this water is heated from the active lava beneath the surface. Apparently, the ancient Hawaiians would come to this location to soak their bodies in the warm, brackish water that was filled with fallen noni fruits and infused with the essence of noni. Apparently, there was some medicinal benefit realized from this practice.

Forests

Noni trees are common forest understory plants in disturbed and native forests near the coastlines of Hawai'i. Noni plants are common companions with kukui nut trees and hala plants (*Pandanus*) and seem to thrive beneath the canopies of much larger plants. Thus, the adaptable noni plant grows well in conditions of full sunlight (lava flows) as well in high levels of shade (forest understory).

Gulches

Noni is a common river or stream gulch plant along the Hamakua coast of the island of Hawai'i, and along gulches of all the major gulches of Hawai'i.

Dry to mesic forests and alien grasslands

The adaptable noni plant, which thrives in tide pools where roots remain wet for long periods of time, also grows well in many dry to mesic forests in Hawai'i and in alien grasslands. For example, in areas along the Kona coast and in grasslands that are covering some of the older lava flows.

Cultivation practices

Planting locations

In Hawai'i, there are several categories of planting location that are defined by the type of soil that exists. On the Big Island, for example, the three types of planting locations include deep soil (e.g., Hamakua coast, Kainaliu and some areas of South Kona), lava rock (e.g., lower Puna, Kona airport Agricultural Park), and mixed lava rock-soil (e.g., Panaewa, Kea'au). Noni plants seem to grow best in rocky soils due to the absence of root-knot nematodes in those sols. However, if root-knot nematodes are not present in deep soil areas, then noni will grow very well.

Propagation of noni

Noni is propagated either from seed or stem cuttings. The primary disadvantage of seed propagation is that without seed treatment, germination takes 6-12 months or more, whereas stem cuttings can be rooted in approximately 1-2 months. The disadvantage of producing plants vegetatively from cuttings is that they may not be as strong and disease-resistant as seedlings, and the trunk and branches may split and break during the first years of fruit production.

Cultivation from seed

Noni seeds. Noni seeds are reddish-brown, oblong-triangular, and have a conspicuous air chamber. They are buoyant and hydrophobic due to this air chamber and their durable, water-repellant, fibrous seed coat. The seed coat is very tough, relatively thick, and covered with cellophane-like parchment layers. A single large noni fruit can contain well over 100 seeds.

Seed collection. Only soft, ripened noni fruits should be chosen for seed collection. The seeds must be separated from the fibrous, clinging fruit flesh. First, split the fruit by hand into smaller pieces. Separate the seeds from the flesh using a strong spray of water and a firm screen or colander, washing the pulp through the screen while retaining the cleaned seeds. Rubbing the fruit fragments on the screen by hand or with a blunt object can help force the fruit flesh through the screen. It may take 15 minutes or more of vigorous washing and rubbing to detach most of the flesh from the seeds.

Seed scarification. Scarifying the hard seed coat by nicking or puncturing it significantly reduces germination time, improves germination percentage, and promotes uniform sprouting. Whereas in nature the seed coat must gradually decompose before water can enter, scarification overcomes this natural seed dormancy. Using a household blender to separate seeds from the ripened fruit flesh can also result in nicking the seed coats, or the seeds can be suspended in water and subjected to short pulses of blending.

Seed drying and storage. Noni seeds can be dried and stored, but the length of time they will remain viable is not known. After cleaning, spread the seeds out on newspaper and dry them in the shade or indoors for

two or three days. Store the seeds in an air-tight container at room temperature.

Planting. Fresh noni seeds can be planted immediately after extraction from the fruit. Some growers soak the seeds until they start to germinate, then plant them in containers, while others plant fresh seeds without presoaking treatment. The seedlings are usually grown for about nine months to a year before they are transplanted to the field. Some growers just plant fruit fragments containing seeds directly into the field soil.

Germination. Noni seeds require hot, wet conditions for optimum germination. Unscarified seeds need several months to a year before natural germination takes place, but their germination can be reduced to a month or so using heat. The seeds can tolerate temperature of 100°F (38°C), perhaps even higher. Select the warmest spot in the nursery or greenhouse to germinate noni seeds. Or, heat can be supplied using nursery heating pads under the seed flats, or by placing the flats or containers in a special "hoop house" covered with clear plastic. If germinated outside, partial sun is preferable to full sun to avoid excessive drying of the medium.

Noni seeds may be germinated in seedling flats or trays or sown directly in containers. A light medium that retains water yet remains aerated is best. Suitable components for a planting medium include vermiculite, perlite, peat moss, commercial potting media, compost, and fine volcanic cinder. For seedling flats, use a light medium, such as one part each of perlite and peat moss, or perlite, vermiculite, and potting soil in a 2:1:1 ratio. For containers, a slightly heavier medium is better, such as one part of perlite or vermiculite and three parts of a potting mix. Fertilizers should not be mixed into the medium, because additional nutrients are not needed until after the plants have their first true leaves.

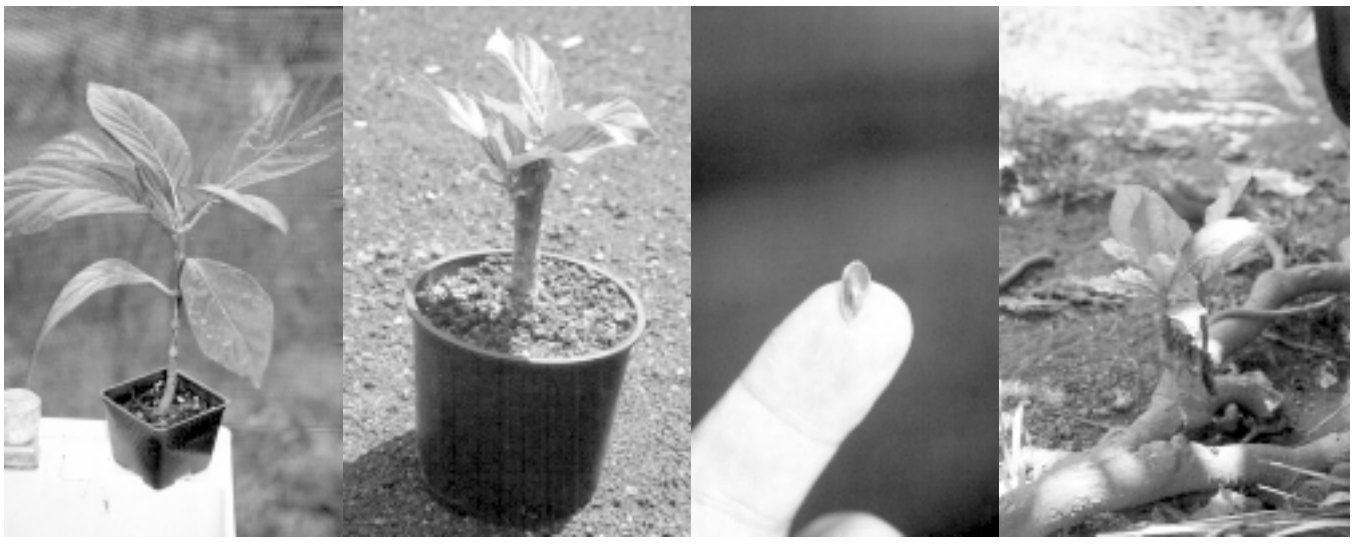
Growth media. Artificial growth media are preferred to field soil for germinating and growing out noni seedlings. These relatively sterile media give the plants the cleanest start, whereas soil (particularly agricultural field soil) tends to contain pathogens that cause plant diseases. For example, many agricultural soils are infested with root-knot nematodes, and noni is highly susceptible to the disease (known as noni root-knot disease) caused by these microscopic, parasitic worms.

Growth containers. Deeper seedling flats are preferred to shallow flats, because seedlings with longer taproots are produced. Seedlings with deep, well established taproots tend to withstand the shock of transplanting better and become established more quickly than seedlings with short misshapen ("J-rooted") taproots.

When seeds are germinated in flats, they should be transplanted into growing containers within a few weeks of germinating. The plant size and vigor achieved depends to a large extent on the size of pot used-the larger and deeper the pot, the larger and more vigorous the noni seedling. "Gallon" pots (about 6 inches in diameter at the top) provide sufficient rooting volume to produce large, healthy seedlings for transplanting. Noni plants can become pot-bound and stop growing if the pot is too small or shallow or they are grown for more than 9-12 months. Fortunately, noni is a vigorous plant with a strong root system that can easily recover from pot-bound conditions once transplanted into suitable field conditions.

Seedling care. Generally, noni seedlings are grown in pots for a minimum of 9-12 months in full sun before

Noni propagation (left to right): plant from seed; plant from stem cutting; noni seed; sprouted noni root on a mature noni plant.



they are transplanted to the field. Seedlings up to 3 years old or more may also be planted.

Seedling fertilizer. Seedlings and young plants grown from cuttings can be given liquid fertilizer once a month, or a controlled-release fertilizer less often (depending on the formulation's release period). Balanced formulations such as 14-14-14 that also contain micronutrients ("minor elements") are advised. Young plants also respond well to applications of dilute, liquid foliar fertilizers. As plants become established, granular, rapidly soluble formulations can be used. Noni is relatively salt-tolerant, and fertilizer burn is uncommon under normal conditions.

Vegetative propagation of noni

Cultivation of noni plants from stem cuttings (verticals or laterals) reduces the time required to obtain plants that are ready for transplanting. Cuttings from stems and branches will sprout roots readily under the proper conditions. A rooting compound may prove helpful in promoting rapid root establishment.

Select vigorous plants for stem propagation. Remove a branch or stem and check for fresh sap flow from the wound. If the sap flows readily, cuttings could be made from these materials. If sap does not ooze from the cut ends, discard the material and select another plant, another location, or perhaps wait for a better time of year. Sap flow indicates a vigorous, actively growing plant with relatively high reserves of energy.

Insert the cut end of the freshly cut noni stem into a pot containing a general-purpose growth medium. Again, an artificial, pathogen-free medium is preferred to untreated agricultural field soil. Select a location with partial shade and keep the cuttings well watered until rooting occurs. After rooting, move the plants into full sun and begin fertilizer applications.

Plants derived from lateral stem cuttings tend to grow in a prostrate habit and may be susceptible to splitting of branches when the fruit load is heavy. Farmers choose to make plants from cuttings because it can save a significant amount of time from planting to first harvest.

Noni plants may also be produced by air layering, or by digging up plants that have sprouted from the root system of a mature plant.

Field cultivation

Site selection

Avoid locations where other crops have been planted recently, due to the susceptibility of noni to root-knot nematodes. Select a site in full or partial sun with well-drained, well-aerated soil. Avoid heavy soils, compacted areas, and flood-prone sites. Prepare a hole about the size of the pot and transplant carefully. In rocky locations, "rip" the land (disturb or plow the sub soil) before grading to prepare a flat or gently sloping field.

Windbreaks

Young noni transplants do not grow well where winds are strong. Such conditions may exist along windward coasts; on the Island of Hawai'i parts of the Hamakua coast and Ka'u are very windy. If a windy site is selected for noni cultivation, windbreaks should be planted for protection. Trees such as eucalyptus, ironwood, or wili-wili planted 150 feet apart are excellent windbreaks for noni. Noni is not adversely affected by planting near ironwood.

Varieties

No cultivated varieties of noni are recognized in Hawai'i, and no germplasm collections are known of anywhere. Another species, *Morinda trimera*, resembles *M. citrifolia* but has smaller leaves and fruits. *M. citrifolia* var. *potteri* is a noni with variegated, green-and-white leaves.

Among noni plants grown in Hawai'i, there appears to be significant, heritable variability in fruit size, shape, and number of seeds. This suggests that through selection, improvement for desirable noni fruit traits can be achieved. For example, one variation among Hawaiian noni plants is referred to as "big-eye" noni.

Planting density

An appropriate interplant spacing for noni is 10-15 feet. At 12-foot spacing there are 290 noni plants per acre. Higher planting densities (closer plant spacing) result in crowding and may exacerbate certain pest or disease problems.

Soils

Noni is an unusual plant, because it can easily tolerate and thrive in a wide range of soils and conditions. In Hawai'i it can grow under almost any soil conditions at low altitudes.

Pruning

Young plants less than 3 years old may be pruned back after or during their first production of fruit. In the following years, the pruned plants will become bushy. Because noni trees can reach a height of approximately 20 feet, growers may wish to prune the vertical branches of mature plants to facilitate fruit harvest. Pruning is an

effective means of disrupting conditions conducive to pest and disease outbreaks.

Nutrition and fertilizer

The amount of nutrients and frequency of fertilizer applications required by noni depends on the soil and rainfall. Noni trees growing in forests usually appear healthy without the benefit of any artificial fertilizers. This suggests that noni may require only small amounts of fertilizer to grow well. In general, however, if intensive fruit production is desired in an agricultural setting, a fertilizer program is recommended. Research is needed to develop the best fertilizer regimes for noni production in the various regions of Hawai‘i where noni might be grown. It is suspected that noni will do best with relatively frequent applications of small amounts of fertilizer. Noni, being salt-tolerant, will also tolerate high levels of fertilizer salts in the root zone without damage or burning to the plant.

The strategy for providing nutrients to noni is similar to that for other fruit crops such as citrus of coffee. Young, non-fruiting noni plants are encouraged to produce lush vegetative growth with balanced fertilizers such as 14-14-14 or 16-16-16, whereas more mature or flowering/fruiting plants are encouraged to produce many large fruits by applying high-phosphorous fertilizers such as 10-20-20 or 1-45-10. Young seedlings and transplants are given controlled-release formulations, while older, mature plants are given rapidly available granular formulations. Fertilizer should be applied away from the trunk of the tree, at the “drip line” of the plant, the area where water drips from the edge of the leaf canopy.

Noni plants of all ages respond well to sprays of foliar fertilizers. Noni flower and fruit production is very responsive to sprays of high-phosphorous foliar fertilizers (e.g., 10-45-10) and products (e.g., seaweed emulsions) containing nitrogen and minor elements.

Noni should be fertilized frequently using smaller amounts of fertilizer, rather than infrequently using larger amounts. In high-rainfall areas, young plants up to a year old can be given 1/2 pound per month of balanced fertilizer (14-14-14), and more mature plants can be given up to 1 pound per month.

Effective organic fertilizers for noni cultivation include crushed coral, dolomite, K-mag, 7-7-7, and composted chicken manure and macadamia nut husks. Some locations will benefit from yearly applications of lime, about 1 pound per plant.

Irrigation

Noni thrives with moderate irrigation and can survive extended periods of drought once established and mature. When plants are less than 2-3 years old and conditions are dry, irrigate once or more a week, applying up to 10 gallons per plant; for older plants, irrigate less frequently. Over-watering can accelerate damage to noni from root-knot nematodes, cause root rot, and leach fertilizer nutrients beyond the root zone.

Harvesting and yield

Noni plants can begin to bear fruit about 9 months to 1 year after planting. Fruits can be harvested at this early stage, although they are generally small and few. Some farmers choose to forgo harvest during the first or second years in favor of pruning back the branches instead.

In Hawai‘i, noni fruits are harvested year round, although there are seasonal trends in the amount of flowering and fruit production that may be affected or modified by the weather and by fertilizer and irrigation. Fruit

Possible yields of noni at various growth stages (see text for assumptions on growing conditions).

Month	Expected fruit yield*
0–9	Seedlings grown in nursery, no fruit production
9	Transplant into field, no fruit production
12–24 (year 1)	2 lbs fruit per plant per month (i.e., 24 lbs per plant per year 1)
24–36 (year 2)	4 lbs fruit per plant per month (i.e., 48 lbs per plant per year 2)
36–48 (year 3)	8 lbs fruit per plant per month (i.e., 96 lbs per plant per year 3)
48–60 (year 4)	15 lbs fruit per plant per month (i.e., 180 lbs per plant per year 4)
60–72 (year 5)	20 lbs fruit per plant per month (i.e., 240 lbs per plant per year 5)

*Realistic estimates based on excellent farm management practices and growing conditions. Actual yields may vary.

production may diminish somewhat during the winter months in Hawai'i. A given noni field is usually harvested from 2–3 times per month.

The estimates for the potential yield of noni plants given in the table are based on a series of assumptions. Please be aware that many factors may diminish yields. Nonetheless, the following estimates are achievable with good farm management and excellent growing conditions.

Yield assumptions: Plant population = 290 plants per acre; good soil fertility and drainage; good water supply; adequate disease, pest and weed control; adequate fertilizer plan (e.g., 6 lbs of 10-20-20 per plant per year).

Therefore, based on this model, at year 5 a farmer can expect to harvest approximately 69,600 lbs of fruit per year per acre, yielding about 35,000 lbs of juice (at an extraction efficiency of approximately 50% by weight). The juice weighs about 9 pounds per gallon, so an acre of well-managed noni can produce approximately 3,800 gallons of juice per year.

For mature trees or farms older than 5 years, yields of up to 500 lbs of noni fruit per plant per year may be realized. However, many factors can impinge on these numbers. Most farmers do not realize the attainable yields due to pest and diseases or poor agronomic practices. On average, one might expect the average farmer to realize yields significantly less than 50,000 pounds of fruit per acre per year.

Noni fruits can be picked at any stage of development, depending on the intended processing method. Some producers prefer green fruits, whereas other processors prefer the hard white noni fruits for processing. Most noni juice processors accept or prefer the "hard white" stage of fruit development for noni juice production, because the fruits ripen quickly once that stage of development is reached.

Noni fruits are harvested by hand by picking the individual fruits from the branches. They are placed in baskets or bags or placed in bins for transport to the processing facility. Noni fruits do not bruise or damage easily, and usually no special padded containers or other precautions are needed to prevent fruit significant fruit damage. Furthermore, exposure of noni fruits to direct sunlight or to warm temperatures immediately after harvest is not a significant concern. So, noni fruits need not be refrigerated after harvest and are usually not refrigerated.

Fruits are washed at the processing facility before they ripen fully and turn soft. For juice production, the noni fruits are held at ambient or room temperature for 1 to several days to ripen before they are processed. However, prompt processing for juice is important, for if ripe fruits are allowed to sit for an extended period, they begin attract unwanted fruit flies, rats and other insects or pests. For processing of noni fruits for powders or other precuts, the fruits may be processed immediately, before they fully ripen. Unripe fruits are easier to work with some types of chopping and drying equipment.

Pests and diseases

Leaf spot diseases

Anthracnose

Anthracnose is associated with a fungus, *Colletotrichum* sp.

Symptoms

Large, expanding leaf spots with dark brown to tan centers and diffuse, rapidly expanding, irregular margins; leaf blight; defoliation.

Epidemiology

The fungal spores of this pathogen are dispersed by splashing water and by wind-driven rain, and land on susceptible noni leaves to start infection. Disease is favored by warm, muggy, wet weather and high relative humidity.

Control

Sanitation (removal of severely diseased leaves; removal and destruction of fallen diseased leaves); ensure good drainage; control weeds to minimize relative humidity in plant canopy; ensure adequate plant spacing to improve air flow in plant canopy; pruning of branches to increase air flow and to remove severely diseased tissues; minimize leaf wetness and avoid the use of over-

Anthracnose lesions on noni leaves

head irrigation; periodic protective spray applications of fungicide(s) approved for use on noni; minimize the spread of pathogen spores on hands and tools during harvesting operations by avoiding infected leaves, if possible.

Risk

The anthracnose pathogen will not attack fruits, but significant defoliation and subsequent yield reduction can occur. The disease occurs primarily in higher-rainfall areas.

Shot hole

The most probable cause of this disease is an unidentified fungal plant pathogen.

Shot hole lesions

Symptoms

Tiny, maroon-colored specks on leaves and bracts that develop into lesions (2-10 mm diameter) with bleached or tan centers and maroon margins. Centers drop out of mature lesions, leaving "shot hole" appearance; premature defoliation.

Epidemiology

Presumably, splashing water, wind and wind-driven rain disperse the fungal spores; disease is favored by warm, wet weather and high relative humidity.

Control

Sanitation (removal of severely diseased leaves; removal and destruction of fallen diseased leaves); ensure good drainage; control weeds to minimize relative humidity in plant canopy; ensure adequate plant spacing to improve air flow in plant canopy; pruning of branches to increase air flow and to remove severely diseased tissues; minimize leaf wetness and avoid the use of overhead irrigation; periodic protective spray applications of fungicide(s) approved for use on noni; minimize the spread of pathogen spores on hands and tools during harvesting operations by avoiding infected leaves, if possible.

Risk

Low to moderate. The disease also does not attack fruits.

Black flag

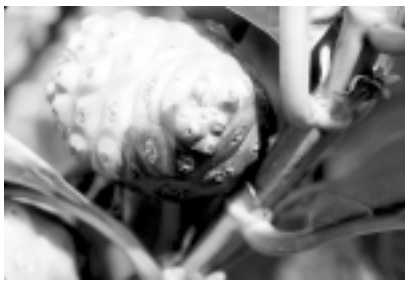
Caused by a *Phytophthora* sp. (a fungus-like organism)

Symptoms

Black leaf spots; leaf blight; brown to black stem blight; soft rot of fruits; fruit mummification; severe defoliation; blackened leaf veins; death of stems; plant death.

Epidemiology

Splashing water, wind and wind-driven rain disperse the fungal spores; disease is favored by warm, wet weather and high relative humidity.



Black flag disease

Control

Sanitation (removal of severely diseased leaves; removal and destruction of fallen infected leaves); ensure good drainage, control weeds, adequate plant spacing, pruning, minimize leaf wetness and overhead irrigation; protective spray applications of approved fungicides; avoid spreading the pathogen on hands and tools during harvesting operations.

Risk

High, but disease distribution is limited at present.

Stem blight

Caused by *Sclerotium rolfsii* (fungus); root-knot nematodes (*Meloidogyne* spp.).

Wilt caused by stem blight

Symptoms

Foliar chlorosis (yellowing) and wilting; stem girdling at or near soil line; internal stem necrosis; stem rot; defoliation; root rot; plant death.

Epidemiology
Disease is favored by flooded or wet soil conditions and predisposing damage by nematodes.

Control
Avoid planting in low-lying areas with poor drainage; avoid plant-parasitic nematodes; avoid injuring stems with weed-whackers; do not pile rocks or un-composted mulch around the base of noni plants; avoid undue plant stresses.


Stem blight

Risk
Moderate to high, as this is a relatively rare disease that occurs only under predisposing conditions. It can be severe when it occurs.

Stem canker
Cause unknown, presumed to be a plant pathogenic fungus.

Symptoms
A progressive rot of stem at the interface between woody and green stem tissues; stem may be girdled and rot, leading to plant collapse and death. Stem lesions are irregular in shape with roughened, dark borders and an overall corky appearance.


Stem canker

Epidemiology
Epidemiology is unknown; no control is known; risk is low to moderate; a rare disease.

Root knot
Caused by root-knot nematodes (*Meloidogyne* spp.).

Symptoms
Foliar chlorosis (yellowing) and wilting; stem girdling at or near soil line; defoliation; root rot; galls and swellings on roots; plant death.


Root knot: stunted plant, galls on root

Stem blight symptoms

Epidemiology

Disease often begins when seeds or cuttings are planted in nematode-infested soil. Nematodes are spread in contaminated soils, media, on tools and shoes and in water runoff.

Control

Avoid untreated soil for noni seedlings; use composts; chicken manure; use of foliar fertilizers; avoid introducing nematode-infected plants to a new field; use of disease-free planting material; moderate irrigation; avoid planting in nematode-infested field soils.

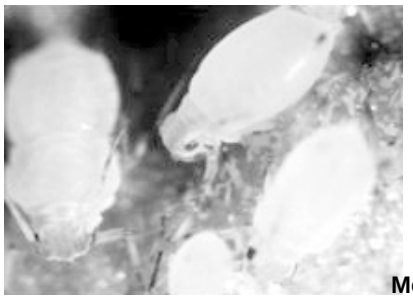
Risk

Extremely high. This is the most important cause of noni plant death and yield loss; widely distributed.

Major insect pests and sooty mold

There are several sap-feeding insects pests of noni that cause direct feeding damage and injury to noni plants. In addition, these pests cause the buildup of sooty mold (a black colored, parasitic fungus) on noni leaves. These sap-feeding insect pests include the following:

Melon aphid
Green scale
Pink mealybug
Spiraling whitefly
Kirkaldy whitefly



Melon aphid

Controlling the pests that deposit the honeydew on noni leaves can control sooty mold. The honeydew is a sweet, sticky substance used by the sooty mold fungus as a food supply.

Additional pests of noni

There are a few minor pests of noni that should be mentioned, as the noni grower is likely to encounter them at one time or another (see photos on next page). Greenhouse thrips may cause some damage if their populations are allowed to develop to damaging levels where noni seedlings are grown under a protective cover, but they usually are not pests of field-grown noni. A parasitic seed plant (*Cassytha filiformis*) may also attack noni, ultimately leading to plant death under certain circumstances. Other minor pests or problems include the

Kirkaldy whitefly

Green scale **Sooty mold**

croton caterpillar, sunburn, or premature and uneven fruit ripening. The cause of uneven fruit ripening is not known, but it is related to uneven fruit growth, development and maturation.

List of approved pest control products for noni in Hawaii

In October 2002 the Hawai'i Department of Agriculture listed the following pesticide products as acceptable for use on noni (*Morinda citrifolia*). Use of products not on this list is prohibited, and label directions must be followed.

Ecozin 3% EC: insect growth regulator
Pyrellin EC: pyrethrin-based, broad-spectrum insecticide
Prentox Pyronyl Crop Spray: pyrethrin insecticide
Trilogy: neem oil (insecticide, fungicide)
Carbaryl 4L: insecticide (non-bearing fruit trees only)
MVPII Bioinsecticide: Bt-based insecticide
Dipel DF: Bt-based insecticide
Match Bioinsecticide: Bt-based insecticide
Clandosan 618: nematicide
Orthorix spray: fungicide
Azatin XL: biological insecticide
Condor Oil: bioinsecticide
Scythe: herbicide
Soil liquid fumigants (preplant):
Tri-Cal Trilone
Tri-Form 30
Telone C-15
Telone EC

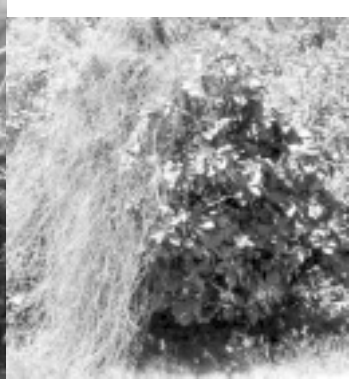
(note: all fumigants are Restricted Use Pesticides)

Additional, minor pests and conditions affecting noni

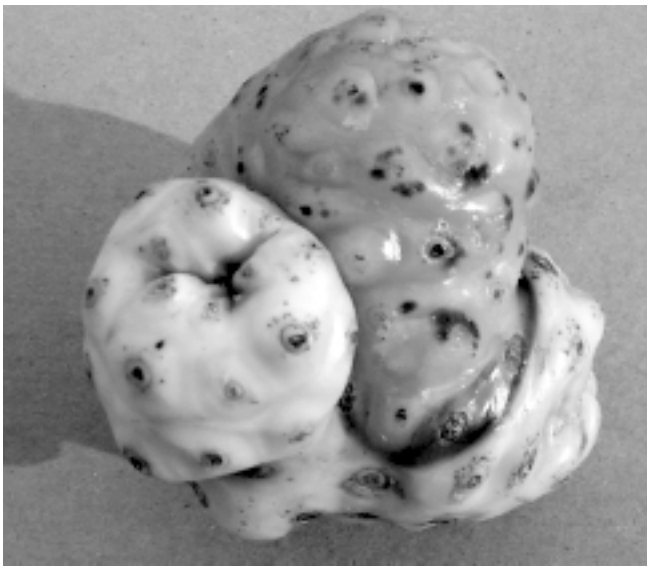
Greenhouse thrips

Sunburn

Croton caterpillar



Cassytha filiformis



Premature or uneven fruit ripening

Economics of noni farming: Production methods and practices

A simple economic model

At the present time (in the year 2002), noni farming can be a profitable enterprise. In this portion of the presentation, I will outline the essential costs and returns for establishing and operating a hypothetical, 1-acre noni farm on the Big Island of Hawaii

Startup costs

I will start with the basic economic projections for this hypothetical 1-acre noni farm, beginning with startup costs. One of the assumptions for this hypothetical farm is that the land is not leased, but rather owned by the farmer. However, whether or not the land is owned by the farmer does not have a significant effect on the gross income generated by the farm. The three primary expenses for establishing the farm are: 1) land clearing (costing approximately $4,000 per one acre of raw land in the Puna District); 2) noni seedling production or acquisition (costing approximately $900 per acre); and 3) land preparation (weeds, planting holes) and planting (costing approximately $500 per acre). Thus the total minimum startup costs for this noni farm are approximately $5,400 per acre. This cost could be significantly higher if planting holes are difficult to prepare or if supplemental irrigation and windbreaks are needed. On the other hand, startup costs could be significantly less if the land has been previously cleared.

Additional assumptions

Following are some additional assumptions to help guide this basic economic projection for a hypothetical, 1-acre noni farm in Hawai‘i:

1) The economic projection is made for a noni farm in its 4th or 5th year of growth (i.e., the 3rd or 4th year of fruit production).
2) There are no significant diseases or pests present (i.e., no root-knot nematodes, no black flag disease).
3) Monthly fertilization (at least 1 pound per month per plant of inorganic fertilizer).
4) Adequate weed management.
5) Noni plant population of approximately 290 plants per acre (12 ft. x 12 ft. plant spacing).
6) No supplemental irrigation (sufficient natural rainfall to ensure good fruit production).
7) Yield per acre per year: 70,000 pounds of ripe noni fruit.

Essential costs: (Total = $14,264 per year).

1) Fertilizer: 12 pounds per plant per year (fertilizer blend is “triple sixteen” or 16-16-16) x 290plants per acre = 3,480 pounds of fertilizer per acre per year. At approximately $1.80 per pound for the fertilizer, the total fertilizer cost is approximately $6,264 per acre.
2) Labor (for harvesting): 12.5 man-hours per week, or 650 man-hours per year @ $10.00 per hour = $6,500.
3) Weed control: $1,000 per year (labor)
4) Materials and supplies: $500 per year.

Projected gross income: Gross income from a hypothetical 1-acre noni farm is presented below, based on three scenarios (farm gate price for fresh fruit, wholesale juice and retail juice production).

1) Fruit (farm gate): 70,000 pounds x $0.30 per pound = $21,400. Profit (income minus costs) = approximately $5,800 per acre.
2) Juice (wholesale): Assuming 60% juice extraction efficiency, 70,000 pounds of fruit yields 42,000 pounds of juice. At a weight of approximately 9 pounds per gallon, that yields 4,666 gallons of juice. At a wholesale price of $20.00 per gallon, the value is $93,320.00)
3) Juice (retail): Retail noni juice prices vary widely. However, assuming a 16 ounce bottle of noni juice retailing at a price of $12.00 per bottle, the value of 4,666 gallons of juice is approximately $447,936.00.

Noni production methods and practices

Noni fruit juices

Noni fruit juice and juice products are processed and prepared in Hawai‘i by a variety of methods. For example, noni juice may be fermented versus unfermented, or fresh-squeezed versus drip-extracted. The “traditional” juice is both drip-extracted and fermented/aged for at least two months. The “non-traditional” method of juice extraction is by pressing or squeezing the juice from ripe fruits. Noni juices may be amended with other additives or diluted, or bottled in its pure state. It may be bottled with or without pasteurization. In this section, the essentials of commercial and home noni juice processing in Hawai‘i are discussed and illustrated.

“Traditional” noni juice: drip-extracted, fermented and aged, unadulterated

The following parapraphs describe the essentials of producing what is sometimes referred to as “traditional” noni juice.

1) Noni fruits arrive at juice processing facility.
Freshly picked, ripening noni fruits arrive at the juice processing facility in a variety of containers. The harvested noni fruits are mainly whitish in color with tinges of green. Unripe, white or yellow noni fruits are very hard-skinned and durable, and therefore resistant to superficial damage and bruising during shipping and handling. They require no special handling. Noni fruits at this stage of development will ripen overnight or in a few days at room temperature and can be processed for juice immediately thereafter.

2) Noni fruits are washed and air-dried. Noni fruits are washed using a variety of methods, including a strong spray of water or by an automated, conveyor-belt driven washing apparatus. Some processors have modified washers previously used in vegetable operations (e.g., for tomatoes, ginger or potatoes).

3) Noni fruits are placed into fermentation containers. Fully ripe fruits contain and release more juice than do under-ripe fruits. The most efficient noni juice extraction by weight is obtained when ripe, soft, translucent fruits are placed into the juice collection vessels. When green or hard noni fruits are placed into a juice collection vessel, the fruits release significantly less juice than soft, ripened fruits and the green fruits release juice that is less sweet and bitterer. Furthermore, a light-colored juice product is obtained from fully ripe, translucent fruits as opposed to the significantly darker-colored juice that is obtained when unripe or green fruits are placed into juice collection vessels.

4) Ripe noni fruits are fermented in a juice collection vessel for 2 months or longer. During this time, the noni juice separates (drips) gradually from the pulp. The juice collection and fermentation vessels should be made of glass, stainless steel or food-grade plastic. The noni juice collects inside the containers and ferments as it gradually seeps and sweats from the fruits. The juice appearance is initially an amber or golden colored liquid that gradually darkens with age. After the collection and fermentation process is complete, the juice is drained from spigots at the base of containers (and filtered). Fresh air is excluded from these containers, and contact between the juice and fresh air is minimized throughout the process.

5) The final noni juice product is decanted, filtered and bottled. Fermented, aged noni juice is a dark brown liquid which is similar in appearance and texture to soy sauce and having similar qualities to a fine wine. The pH is relatively low (approximately 3.5), lending a characteristically sour taste to aged noni juice. After approximately 2 months, most of the noni juice separates naturally from the fruit pulp and may be drained from the container and filtered. The recovery of juice by this traditional method is approximately 40%-50% of the original fruit weight. Therefore, using this method, 100 pounds of fruit may yield about 40-50 pounds of juice, or about 4.5 to 5.0 gallons of juice. After all of the noni juice is drained from the collection and fermentation vessel, the residual pulp may be pressed to express the remaining juice fluids. The leftover pulp and seeds may be discarded, or they may be dehydrated and used in other noni products.

Pasteurization

Noni juice products in Hawai'i are either pasteurized or not pasteurized. Pasteurization does appear to alter the flavor of raw noni juice. Because fermented noni juice usually has a low pH (approx. 3.5), pasteurization may not always be necessary.

Non-fermented noni juice

Some Hawai'i noni juice producers and consumers prefer a lighter-colored, sweeter-tasting product. If the noni juice is not allowed to ferment in the collection vessel, the juice will retain a relatively fruity, sweet taste, rather than the bitter, sour taste associated with fermented noni juice. To obtain sweeter, fruiter juice, the juice is drawn off from the collection vessel every couple of days, and not allowed to ferment. Rather, the juice is bottled it and refrigerated (or frozen) immediately or until it is marketed or consumed.

Light and temperature considerations

High levels of light exposure to the juice and high temperature during juice collection and fermentation may cause undesirable chemical reactions to occur in noni juice. Nonetheless, noni juice is produced under a wide range of temperature and light conditions in Hawai'i. For example, many backyard noni juicers place a large glass jar with noni fruits out in the direct sun for many months before consuming the juice. However, probably the most consistent commercial juice products are obtained where both temperature and light are regulated during the fermentation and storage periods.

Bottling

Most noni juice producers bottle their products in either clear glass or clear plastic bottles. Glass is preferred to plastic for longer shelf life and quality control, as plastics may allow some oxygen to enter the container. How-

ever, glass is heavier and more expensive to ship than plastic. Hawai‘i noni juice producers rarely use dark glass. Because light and oxygen tend to diminish a product’s shelf life, choice of bottling container may be a significant consideration.

Fresh-squeezed noni juice (filtered, refrigerated or pasteurized)

Fresh-squeezed noni juice has a sweeter (less acidic), fruitier flavor than aged, fermented noni juice. When noni fruits are ripe, the juice is separated from the pulp and seeds using a fruit press. Up to 65% juice recovery by weight is possible using this method of juice extraction. Home producers of noni juice use a wide range of fruit pressing methods, from squeezing by hand through cheesecloth, paint strainers, to more elaborate homemade pressing devices.

Some noni juice producers use a hydraulic fruit press such as a bladder press for making fresh-squeezed noni juice. Ripe fruits are loaded into the press through the top door. Juice is pressed from the pulp and bottled immediately.

Fresh-squeezed noni juice has a golden amber color and has significantly less sediment than fermented noni juice collected by the traditional method. Conversely, fermented noni juice produced by the traditional method is very dark brown, resembling the color and texture of soy sauce.

Fermentation of fresh-squeezed juice can be arrested by refrigeration or by pasteurization. This will preserve the fruity, sweet taste of the non-fermented juice. Or, the fresh-squeezed juice may be allowed to ferment naturally in bottles or containers for a period of weeks or months prior to marketing or consumption.

Amended or flavored noni juice products

Noni juice may be mixed with other juices of flavorings to improve the palatability of the product (e.g., with raspberry, strawberry, or grape flavors). Some producers choose to dilute their juice with water and sweeten the product with the addition of sugar.

Noni juice concentrate

Using flash evaporation technology, producers may produce noni juice concentrate.

Reconstituted noni juice

Noni fruit pulp may be chopped, dehydrated and powdered prior to using it in reconstituted noni juice products for the dietary supplement industry. These products are standardized to approximately 0.8% noni active polysaccharides (which is equivalent to the noni active polysaccharide content of pure aged noni juice).

Noni fruit and juice powders

Noni fruits in Hawai‘i are processed to produce dried powders derived from whole fruit, de-seeded fruits, and juice. Noni juice itself may be evaporated and formed into a powder that can be used in various products, including reconstituted juices. Noni juice powder is highly hygroscopic (attracted to water) and must be mixed with a non-hygroscopic carrier to enable it to retain its powdered formulation.

Quality control issues

There are a number of significant quality control issues that may impact the good reputation on Hawai‘i noni juice products, including product dilution (or amendments), product contamination, chemical residues, lack of standardization for biologically active ingredients and poor product consistency (e.g., significant variability in juice attributes).

Product dilution and amendments

Some juice producers choose to add sugar to their raw juice products without informing their clients. This practice may lead to a significant amount of alcoholic fermentation if contaminating yeasts are present in the juice. Other producers water down their juice products, an unfortunate practice which affects the levels of biologically active compounds in noni juice.

Hygiene and sanitation

Some noni juicing facilities in Hawai‘i have relatively unsanitary conditions or poor worker hygiene. This can result in juice products that are contaminated with unwanted microorganisms.

Chemical residues

Fruits that are not washed or plants and fruits that are sprayed with pesticides may result in juice that has chemical residues within.

Lack of standardization

Many noni juice producers are not aware of which biologically active ingredients they can or should be considering when striving to produce a standardized, consistent juice product.

Tips for the home noni juicer

Following is a set of useful tips for the home producer of noni juice products.

Hygiene

Strive for a clean, sterile environment in the juicing area. Tools and containers may be sterilized using hot water or simple soaps and disinfectants. Personal hygiene of the juicing personnel is another important consideration.

Oxygen

Try to exclude air and oxygen for the juicing containers. The fermentation of noni juice is accomplished by an anaerobic process (does not require oxygen), i.e., by bacteria that do not explicitly require oxygen for the fermentation process. However, do not enclose the fruits in the collection vessel using an airtight seal on the vessel, because the process of fermentation leads to the evolution and accumulation of gasses within the vessel that may build up potentially explosive pressure if not released. Thus, the use of some type of fermentation lock is recommended (i.e., a device that allows the exit of fermentation gasses from of the container while disallowing the entry of unwanted air and airborne contaminants).

Juice color

The color of juice may be modified (darkened) by adding green fruits to the juice collection vessel. If green fruits are cut up before being placed into the juice collection vessel, the cut surfaces will quickly oxidize and turn brown, lending a overall brown color to the juice that drips from them. For lightest-colored juice, juice is collected or processed immediately from ripe fruits and not allowed to ferment (i.e., the juice is refrigerated it or pasteurized).

Filtering of sediment

Juice may be filtered and clarified using silkscreen (from art supply store) or paint strainers (from hardware store). Filters or strainers can be sterilized in boiling water before they are used.

Quality control

If juice appears overly cloudy or has an unusual or foul flavor or high pH, it is probably contaminated and should be discarded.

Wild noni picking "kokua"

When picking noni fruits from wild plants, use care not to damage or break the extremely brittle branches of the noni plant.

Containers

Avoid using plastic containers for juice collection or storage (i.e., plastic garbage cans) that are not food-grade plastics, as they may release undesirable chemicals into the juice.

pH

Obtain an inexpensive set of pH papers to monitor the pH of your juice. Good, aged noni juice should have a pH of 3.5 or less. If the juice pH greater than 3.5, there is a higher probability that it may be contaminated with undesirable organisms.

Labeling

The major advertising claims about the healing powers of noni have not yet been evaluated by the Food and Drug Administration (FDA), and noni (*Morinda citrifolia*) does not yet appear on the FDA's GRAS list, i.e., the list of foods and food additives that are "Generally Recognized as Safe" by the FDA. Therefore, for home bottlers of noni juice who plan to label and market their product, it would be wise to include on the label the following or similar disclaimer: "These statements have not been evaluated by the FDA. This product is not intended to diagnose, treat, cure or prevent and disease."

Storage

Fresh-squeezed noni juice should be refrigerated. Aged, fermented noni juice can be stored at room temperature indefinitely.

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Following is a relatively comprehensive and up-to-date bibliography for published information pertaining to noni. The following bibliography is arranged according to the following headings:

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