FARMER'S BOOKSHELF

An information system of tropical crops in Hawaii
Department of Tropical Plant & Soil Sciences
University of Hawaii at Manoa

Macadamia

TOPICS:

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Australia's Most Delicious Bush Nut. Australian National University
Australian Macadamia Society
The California Macadamia Society
Macadamia, California Rare Fruit Growers
Macadamia--General crop information, Knowledge Master, CTAHR
Macadamia integrifolia Maiden & Betche, Purdue University
Macadamia Production in Southern California, Purdue University

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Botany

The macadamia nut is native to the coastal rain forest areas of south Queensland and northern New South Wales in Austrialia between 25 and 33 S latitude. It is a subtropical nut and belongs to the same family as protea.

Two species that produce edible kernels are *Macadamia integrifolia*, the smooth shell macadamia, and *Macadamia tetraphylla*, the rough shell macadamia. Both species are evergreen trees, often as tall as 60' spreading as wide as 40'. They have shiny, green, holly-like leaves. *M. integrifolia*, the smooth shell, is the most important species.

The fruit is a follicle with a dull green pericarp (husk) that opens along one line enclosing a seed (kernel, nut) in a hard seed coat (shell).

Smooth shell

The nutrient composition of the roasted kernel (4 oz):

energy	**820 calories**

moisture	**1.2- 1.5%**
protein	**9 %**
fat	**78 %**
total carbohydrate	**10%**
fiber	**1.8 %**
calcium	**53 mg**
phosphorus	**240 mg**
iron	**2 mg**
vitamin a	**0**
thiamin	**0.2 mg**
riboflavin	**0.1 mg**
niacin	**1.6 mg**

Leaves are 5 to 10 inches long, usually three at the same node. Some cultivars (varieties) have smooth leaves, others have leaves that are more spiny on the edges. Flower spikes are produced in racemes (clusters) 6 to 12 inches long consisting of hundreds of small cream-colored perfect flowers. However, seldom do more than 10 nuts set on a mature raceme.

Rough shell

This species (tetraphylla) produces slightly spindle-shaped fruits (nuts) with rough pebbled surfaced husks. The leaves are 10 to 20 inches long and produced in clusters of four, with spiny edges. Flowers are pink, and the clusters are 8 to 15 inches long.

The kernels have less oil and more sugar and though sweeter when eaten raw, results in a darker nut when roasted of low quality.

Flowering and Nut Set

- Contrary to Australia, many growers in Hawaii note that the flowering period tends to lengthen as an orchard matures, which may help to compensate for poor conditions, pest or disease problems during a particular time. The natural maturation and drop of macadamia nuts in Hawaii extends over periods of several months and in some cases appears to be increasing. For the small grower who depends upon family labor and for some processors, this is an advantage.
- For larger growers, it would be ideal if macadamia could be cycled so that the maturation and drop of nuts could be programmed over an extended period. High density nuts could be harvested with less labor.
- Ethephon (Ethrel) is cleared for use to enhance nut drop (abscission). Field research on 333 indicates that application of ethephon at 400 to 500 ppm should be timed 26 to 33 weeks after maximum flowering to achieve the most rapid and complete response. Yield 1 to 3 weeks after treatment was increased, but total yield (5 weeks after treatment) was not different from the unsprayed trees. However, some defoliation of the older leaves is likely (Nagao, 1986, Proc. HMNA). Field research is continuing.
- A combination of Ethrel treatment with mechanical shaking has resulted in some increase in total sugar content and some decrease in percentage of No. 1 nuts. This indicates that some immature nuts are included in the drop and suggests successful application is most likely where flowering is also controlled.

  One of the factors affecting flowering is temperature. In growth-room experiments, it was shown that more profuse flowering resulted from night temperatures of 15° to 18°C (59° - 64°F) than at higher night temperatures. However, this control is not absolute, since eventually some flowering resulted when night temperatures were 21°C (70°F). These results seem to corroborate the frequent observation that macadamia flowers and matures earlier at higher than at lower elevations.
- Further experiments suggest that nut formation has a higher optimum temperature range than flower formation. Hence, overall response to temperature may be more complicated than thought previously.
- The economic importance and the cause of the shrivel kernel problem are not known.
- Nut set and premature nut drop.
  1. Periods of high nut drop have been identified in several varieties and appear to correlate with the onset of exponential fruit growth (4-6 weeks after anthesis).
  2. Measurements of ethylene production by intact racemes have shown higher ethylene levels associated with periods when nuts undergo heavy drop (4-6 weeks after anthesis). These experiments suggest that high ethylene production may be responsible for premature drop of macadamia in the laboratory and under field conditions.
  3. Abscission of young fruits in the field and on explants (in vitro) can be stimulated by ethylene. Ethylene inhibitors such as silver nitrate and aminooxyacetic acid delayed abscission of young macadamia nut explants. As fruits attained full size, sensitivity to ethephon decreased. As fruit reached maturity and began abscising, ethephon again promoted abscission.
  4. Experiment with explants indicated that the growth regulators, NAA & 2,4-D, can inhibit abscission of nuts in vitro. Gibberellic acid

(GA3) and benzyladenine (BA) had no effect.

5. When individual racemes in field trials were treated with GA3, NAA, or 2,4-D, GA had no effect in these experiments. NAA at 1.0 mM stimulated abscission of young fruits, whereas 0.01 and 0.1 mM had no effect. A temporary inhibition of nut drop was evident after treatment 0.01 and 0.1 mM 2,4-D; reapplication stimulated abscission.

- Preliminary experiments with N, P, K and zinc fertilization have shown that inclusion of zinc-containing fertilizer significantly increased fruit set early in the season. Yields were also significantly increased by the N, P, K, and zinc treatments. Preliminary experiments at a commercial orchard suggest that supplemental irrigation during dry conditions reduces premature nut drop.
- Girdling, when done to the entire tree at the early flowering stage, enhanced flowering 14 to 18 weeks after treatment, and greater fruit set was observed. Girdling at the maximum flowering and end of flowering did not affect flowering.
- Nut thinning experiments, in which number of nuts per raceme were varied 4-5 weeks after anthesis, showed initial nut set affected final nut set. Percent nut drop was unaffected. Nut thinning experiments done on girdled branches showed final nut set and percent nut drop were affected by girdling. Studies are currently in progress to determine the relationship between leaf area and premature nut drop.
- Results of recent experiments (unpublished, Nagao) on flowering have shown that gibberellic acid (GA3) at 200 to 1,000 ppm inhibited flowering of young trees when applied prior to the flowering season. A commercial formulation of GA3 (Pro-Gibb) at 2,340 ppm also inhibited flowering. No deleterious effects on vegetative growth were evident following treatment, nor was flowering in the subsequent season affected. Experiments with the GA antagonist, daminozide or succinic acid-2,2-dimethyl hydrazide (SADH), at 700 and 7000 ppm applied at the same stage slightly inhibited flowering. Ethephon at 100 to 500 ppm hastened flowering and shortened the duration; total number of racemes was not affected.
- Preliminary results of photosynthesis experiments revealed that leaves grown in full sun were saturated (maximum level of photosynthesis) at light intensities 70% of the intensity at noon. As leaves were grown in shade, leaves were saturated at increasingly lower levels of light indicating adaptation to shade.
- Recent research in Israel indicates that air layered trees begin bearing several years before grafted trees. Earlier bearing would start positive cash flow earlier, enable growers to adopt new cultivars by reducing the time orchards are non-productive, and help to control tree size permitting closer planting. Research with Paclobutrazol (Cultar), a growth retarding chemical, should also be initiated to control size and promote early production.

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Climate

The following set of environmental conditions fall within the acceptable range for macadamia production in Hawaii:

- **Soil**: well-drained a'a lava land that is sufficiently developed or weathered to support a solid cover of natural vegetation, or other deep, well-drained soil with pH range between 5.5 and 6.5.
- **Rainfall**: 60 to 120 inches a year; 80 inches or more for lava land.
- **Elevation**: Sea-level to 2,500 feet.

Optimum yields occur in areas with maximum temperatures less than 90°F (32°C) and minimum temperatures greater than 55°F (13°C).

A rule of thumb offered by some Australian scientists and supported by several Hawaii scientists when considering planting outside Hawaii is not to plant between 0 and 25 N or S latitiude.

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Educational Programs

- CTAHR provides information on production and marketing, and support to grower and processor organizations through the Cooperative Extension Service. County Extension agents with responsibility for fruit crops (including macadamia) are located on the Big Island, Kauai, Maui, Molokai, and Oahu. These agents are supported by a commodity extension specialist responsible for avocado, coffee, guava, and macadamia located at the Manoa campus.

  Other discipline extension specialists with some assignment in macadamia include agricultural economics, entomology, food science, soil science, and weed control and are all located at the Manoa campus. Two more specialists in pathology and agricultural economics with some assignment in macadamia are located in Hilo.

- Two agents cover macadamia on Big Island; however, the agent on the Kona side is responsible for all horticultural crops in Kona and Kohala. As this is a major macadamia, coffee, and avocado area and one with an expanding landscape industry, he is unable to cover any crop in depth. Another agent is needed in the Kona-Kohala area.

- In addition to insufficient time to handle in-depth educational and applied research programs at the extension agent and to a lessor extent at the specialist level, budgets are insufficient to support travel--intraisland or interisland and other operations.

- Most of the growers have small orchards, < 10 acres, though most the acreage is on a few large corporate farms. Educational meetings are scheduled during the evenings or weekends as small growers generally have off-farm jobs.

- Ag consultants and production management firms have gained popularity in some parts of the US, particularly, Florida and California. Absentee investors frequently utilize these services, but the vast majority of growers in Hawaii cannot afford consultants and depend on advice from agents. Corporate farms have their own staff and frequently work directly with CTAHR (College of Tropical Agriculture and Human Resources) scientists.

- New strategies to handle the increasing number of requests by growers for on-farm visits, walk-in conferences, workshops, special programs, and applied research must be developed. The use of video taped programs of field days and specific production tasks is being explored. A video bulletin on a small innovative grower has been edited. Agents also encourage local grower groups to sponsor field days to share production skills and as venue for agents to work with larger numbers of growers.

- TPSS Department scientists have developed an information system on tropical crops in Hawaii called the **Farmer's Bookshelf**. Originally developed in 1988 for use on Macintosh computers, a Windows version was later added. Currently, the Macintosh and Windows versions are no longer supported since the Farmer's Bookshelf was put on the World Wide Web in 1997.

  Since 1988, the Farmer's Bookshelf has been expanded to include other fruit and nut, vegetable, and ornamental crops.

- The last major extension bulletin on macadamia was published in 1984. A short bulletin, HITAHR Brief No.057, was published on weed control in 1987. The 4th Macadamia Industry Analysis (1987) was released as a bulletin.

- The macadamia specialist also edits and video tapes the proceedings of annual meeting of the H.M.N.A. which provides additional technical information the more educated growers, ag consultants, extension agents, and other scientists.

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Computerized Macadamia Costs Analysis

The Macadamia Cost Analysis file for macadamia has been developed by Dr. Kent Fleming, fleming@hawaii.edu, TPSS Dept., CTAHR (808-322-9136), to help farmers determine their costs and profits. Simply read the brief instructions at the top of the file when it opens. Type in your numbers where or use the 'typical farm' numbers in the bordered boxes, the analysis is automatic. You will need a spreadsheet program such as Lotus 1-2-3 or Microsoft Excel.

A printout of this analysis for a typical farm is shown in Hawaii Macadamia Nut Assn. (1992) 32nd Annual Proceedings, p. 65.

Cost of Analyis Spreadsheet

EXTENSION BULLETINS

Economics of Macadamia Nut Production in Hawaii by Dr. Frank Scott (Research series 059, 1989) is available from most Cooperative Extension Service offices in Hawaii. This publication considers startup and annual costs yearly, based on 25, 50, 100, and 500 acre farm size.

Annual per acre net returns to land and risk for the four farm models at year 16 indicate substantial economies of scale, ranging for $3,075 for the 25 acre to $3,853 for the 500 acre farm at an in-shell price of 90 cents per pound and an in-shell yield of 6,500 pounds per acre. Use of mechanical harvesters contributes to the greater efficiency of the larger models, with shakers becoming economically feasible at year 12 for the 100 acre farm and year 8 for 500 acre farm. Substantial economies of scale are also reflected in orchard development cost, which is considered the total cost of financing the orchard through year 6 and ranges from a high of $17,250 per acre for the 25 acre farm to a low of $13,780 for the 500 acre farm.

Internal rate of return before tax (pre-1987) at an in-shell price of 81 cents per pound (approximately the current level) and inflated at 5 percent annually is submarginal for all six models ranges from 15.3 % for the 25 acre farm to 19.3 % for the 500 acre farm.

For smaller farm sizes, HITAHR Brief 009, *Economic viability of small macadamia nut farms in Kona* written by Scott and Marutani 1982 might be helpful. This out of print bulletin may be available at Cooperative Extension Service offices in Hawaii.

Cultivars

- The following cultivars are recommended by CTAHR:

  'Purvis (294) - produces large kernels of exceptionally good quality and flavor.

  'Kau' (344) - hardy, upright tree well adapted to elevations from 500 to 2000 ft.

  Average Yield, Waikea Experiment Station:

  5970 lbs WIS, 1920 lbs. of kernels, 1560 lbs. No.1 kernel per acre.
  (Ito, Hamilton and Hirae, 1983, *Tropc. Agric.* 60:64-65).

  'Kakea' (508) - very heavy producer of high quality nuts and kernels over a 5 to 6 month harvest period, somewhat susceptible to 'stick-tight' nuts.

  Average Yield, Waikea Experiment Station:

  5520 lbs WIS, 1930 lbs. of kernels, 1663 lbs. No.1 kernel per acre.

  'Keaau' (660) - upright tree with excellent nut and kernel characteristics, crop matures over a 3 month period.

  Average Yield, Waikea Experiment Station:

  4780 lbs WIS, 1750 lbs. of kernels, 1500 lbs. No.1 kernel per acre.

  'Mauka' (741) - hardy tree which performs well from 1500 to 2000 ft. elevation.

  'Pahala' (788) - narrow and upright tree with excellent nut and kernel characteristics.

  'Makai' (800) - produces excellent kernel quality and is adapted to 500 to 1800 ft. elevations.

- Some large growers prefer cultivars with short harvest seasons, while some small growers prefer cultivars with longer harvest seasons; both types are available.
- Some processors do not want a short harvest season because this would create shelf-life, storage, and capital problems.
- Current selection standards used by the CTAHR breeding program strives for:
  - in-shell yields of 150 lb per tree at 10 years, at good sites and 80 lb. at less favorable sites;
  - there should be few to no 'stick-tights', 60 to 85 nuts per pound with 37 to 45% kernel, at least 95% grade 1 kernels with specific gravity < 1.0, kernel appearance score of 3.0 to 3.5 on a scale of 4.0;
  - the tree should be narrow and upright with strong crotch angles to permit a tree spacing of 20 x 30 ft. without shading adjoining trees.

- A project funded by a USDA section 406 grant is evaluating different cultivars for postharvest problems caused by genetic susceptibility to rancidity.
- From current indications, including new selections and genetic material on hand, in-shell production per tree can be increased by at least 25%, the percentage kernel recovery increased from 35 up to 45%, the percent of grade 1 kernels per tree can be increased from 85 to 95% with new cultivars. The potential increase would amount to approximately 80 percent higher yield of grade 1 kernels.
- Cultivars with good yields at altitudes up to 2000 ft. are 'Mauka' - 741, 'Keaau' - 660, 'Kakea' - 508, and several unnamed selections. A longterm, replicated evaluation program organized to collect yield, growth, and to observe genetic x environment responses of different cultivars in a range of ecozones and locations is only partially organized.
- Selections resistant to the root disease *Kretzschmaria clavus* root rot are needed. Two projects have been initiated to screen seedlings as possible rootstocks resistant to *Kretzschmaria clavus*.

- Vigorous-growing rootstocks adapted to problem soil areas such as the low pH, phosphorus-fixing, high manganese and aluminum soils are needed. At present, there is only limited information on rootstocks. *M. tetraphylla* is not recommended at a rootstock for Hawaii due to questionable performance.
- Growers sometimes experience reduced nut quality when nuts are left longer than a month on the ground particularly with the cultivars 'Keaau' - 660 and 'Mauka' - 741. Germination tests are included in the current selection program to discard plants which tend to germinate quickly.
- Limited amounts of scionwood of new cultivars can be obtained from CTAHR as they become available. Large and small growers are also sources of propagating materials when commercial quantities of scions are required as there is not a developed commercial nursery industry for macadamia plants comparable to other mainland fruit crops.

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Diseases

- A fungus, *Kretzschmaria clavus*, was isolated from decayed roots of macadamia and shown to be the causal organisms of root rot on healthy macadamia trees. An estimated 6,500 acres of bearing and non-bearing macadamia trees or 44.2% of the total acreage in the State of Hawaii are currently planted in areas where *K. clavus* has been identified. In Hilo and vicinity, more than 80% of declining macadamia trees had extensive root rot caused by *K. clavus*, and the severity of tree decline was positively correlated with the amount of root rot. *K. clavus* is only one of several types of decline.
- Trees that decline are usually 10 to 12 years old. The effect of *K. clavus* on younger trees is not known. It is sometimes difficult to re-establish a tree in the area previously occupied by a tree that declined.
- *K. clavus* was found on trunks of dying or dead *Melochia indica* and *Cecropia peltata* in ohia forests near the macadamia orchards with K. clavus root rot in Keaau. The fungus isolated from these two species of trees was capable of infecting healthy macadamia trees. This indicates the possibility of reducing the damage by *K. clavus* in the new plantings by changing cultural practices. Instead of the conventional practice of incorporating the stem tissues of forest trees into the soil, they should be removed from the field.
- The following field observations suggest that root rot of macadamia caused by *K. clavus* may also be air-borne:
  1. Kretzschmaria root rot of macadamia occurred in a field previously planted with sugarcane.
  2. In a rainy area, the tree death rate was relatively high. More than 50% of macadamia trees were killed by *K. clavus* within 5 years.
  3. In the same area, infection originating from a branch more than 1 m above the ground was observed on several macadamia trees. The source and origin of air-borne infection is still unknown. This information is vital for the development of control methods.
- Obstacles to finding an effective fungicide control program for *K. clavus* are:
  1. The early stages of infection are difficult to detect.
  2. Most systemic fungicides are xylem translocated so the they move to and accumulate in the leaves. A downwards mobile fungicide would be most effective for *K. clavus* control.
- The industry is surveying its orchards to identify possible root rot resistant rootstock. There is no evidence yet of such a rootstock. Furthermore, present commercial varieties are susceptible to air-borne infection by *K. clavus* which a disease resistant rootstock would not protect. Acreage within the affected areas is expected to increase considerably before a disease resistant rootstock can be identified and propagated for commercial planting.

  Macadamia seedlings inoculated with *K. clavus* grown in wheat and oat medium died within one month in preliminary tests. This method is currently being used to screen macadamia seedlings for resistance to *K. clavus*.
- Botrytis blight occurs on macadamia blossoms only after anthesis or on senescent flower parts. Flower buds and even very young nuts are not susceptible.

  Phytophthora blight occurs only after prolonged periods of continuous rain. Infected racemes and nuts were found only on particular branches or sections of a tree rather than distributed evenly throughout the tree because the fungi produced only a few sporangia on racemes and none on the nuts. As soon as the rains subsided, no further spread was observed. Even with occasional light rains and 100% relative humidity every night, the pathogens did not become active again.
- Botrytis and Phytophthora blights may only be a problem 2 out of 5 years and are generally not considered serious except for localized outbreaks. The effects of these blights could be magnified if the flowering season were concentrated in a short period of time. Benlate at 1-3/4 lbs. per acre and Difolatan at 114 lbs per acre are recommended for these blights. Only the large growers have a spray

program.

- Experiments performed by CTAHR have not demonstrated increased yield to result from control of these organisms. However, industry says it has experienced as much as 30% reduction in yield from the blossom blights.
- Since these fungi might develop resistance to Benlate (as in the case of Botrytis) and Difolatan has been discontinued by Ortho and only remaining stocks will available, alternative chemicals should be identified and registered.
- Ridomil was found to be effective in field tests but only at 2 and 4 oz. (active) per square meter applied as a drench. This rate is not cost effective. Because of resistance problems Ridomil 2E will not be registered for foliar applications. Aliette, a product specific to Phytophthora and Ridomil MZ 58, a combination of Ridomil and Mancozeb has shown efficacy in controlling Phytophthora blight in limited field testing. Further testing and residue analysis are continuing.
- A flower blight scouting program could be feasible because of the macadamia blooming cycle. Flowers could be collected and checked to determine if population levels of the fungi have reached economic thresholds. Scouting could begin with early bloom and collections could be made from representative areas. Results could then be returned by electronic mail to initiate fungicide applications if required. Correlation of collection information with weather data could provide the basis for a future forecasting system.
- *Phytophthora cinnamomi* causes stem canker of macadamia. It is relatively rare, but increased incidence of this disease has been associated with poorly-drained sites, seedlings planted too deeply, and mechanical injuries.

Macadamia plant disease pathogens, Knowledge Master, CTAHR
Hawaii Pesticide Information Retrieval System Home Page, CTAHR

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Fertilization

- The fertilization practices for a location should be determined by monitoring the concentration of the major nutrients in the leaves annually or more frequently. The standard procedure for collecting leaf samples for tissue analysis and interpreting the results is described below based the work of Dr. Bruce J. Cooil, Ag. Botany, CTAHR, and modified in 1987 by Dr. John E. Bowen, Plant Molecular Physiology (Proceedings 27th Annual Meeting of Hawaii Macadamia Nut Assn.)

Leaf Sampling:

Leaves are sampled during the month of the year when the major flush of growth is beginning. At Keaau Orchard, this is generally in March. Branches are selected on which new growth is just beginning. (We have used only such branches which can be reached from the ground, as branches higher in the tree would require more labor than available.)

From each selected branch, one mature leaf is taken from the second whorl below the newly developing flush. Where single trees are sampled, the sample should contain at least 8 leaves, each from a separate branch. The selected branches should be obtained from different positions around the tree. If samples are being composited from several trees, ordinarily a minimum of three leaves should be obtained from each tree.

For analysis of N, P, K, Ca, and Mg, the sample should contain at least 8 leaves. If minor elements are also to be determined by chemical methods, the sample should consist of at least 15 leaves.

Interpreting Analytical Results:

For leaves sampled as described above, interpretations of nutritional status have been made as shown below. These values are based on experiments with 'Keauhou' (246), 'Kakea' (508), and 'Ikaika' (333) and recent work on seedlings of 'Keaau' (660) and 'Pahala' (788).

Results indicate that the critical ranges for nutrients are similar in these tree selections. Insufficient information is at hand to determine whether this is also true of other selections. Values are reported on the basis of leaf dry weight and dependent upon on the relative concentration of the nutrient in percent or in parts per million (ppm) also called g/g.

a. Nitrogen (N): Young trees before bearing age should have leaf nitrogen values in excess of 1.50 percent (dry weight basis) for maximum growth rate. Leaf concentrations below this are generally associated with light-green or yellowish color. In older bearing trees, the leaf nitrogen may go as low as 1.45 percent N without loss in yield.
b. Potassium (K): Potassium concentrations of 0.45 percent of the leaf or above clearly denote adequacy for growth of young trees and yield of bearing trees. Concentrations below 0.30 percent K generally denote deficiency, which may become severe. Severe leaf scorch is found in this range. In the range between 0.30 percent K and 0.45 percent K, deficiency may develop if potassium is not available at all times, as may result if applications are infrequent. Recent work on seedlings of 'Keaau' (660) and 'Pahala' (788) suggest slight deficiency at 0.45 percent but good growth at 0.6 percent.
c. Phosphorus (P): A leaf concentration of 0.08 percent P (dry weight basis) or above is needed for maximum growth rate of young

trees. To assure maximum yield of bearing trees, a value of 0.08 or higher should be maintained. Leaf phosphorus percentages above 0.20 percent of dry weight are associated with chlorotic and firing symptoms, so should be considered excessively high.

In soils having low phosphorus-fixing capacity (e.g., unweathered lava), excessive phosphorus can lead to immobility of iron in the plant and the appearance of iron-deficiency symptoms (chlorosis in leaves); under such conditions, a phosphorus level of 0.12 percent can be excessive.

d. Magnesium (Mg): Leaf magnesium values of 0.065 percent (dry wright basis) or below are definitely associated with an interveinal chlorotic mottling of older leaves. However, no response in growth or yield has resulted from application of magnesium to 'Keauhou', 'Kakea', or 'Ikaika' even in this low range. Recent work on seedlings of 'Keaau' (660) and 'Pahala' (788) suggests that below 0.09 to 0.10 percent is inadequate for maximum growth.

e. Calcium (Ca): Leaf calcium values of 0.65 and above are considered adequate, 0.55 is the critical minimum. Recent work on seedlings of 'Keaau' (660) and 'Pahala' (788) suggests that deficiency symptoms are present at 0.57 percent.

f. Iron (Fe): Recent work on seedlings of 'Keaau' (660) and 'Pahala' (788) suggests that leaves containing 60 ppm Fe were free of deficiency symptoms, but symptoms were observed at 33 ppm. In bearing trees this value maybe be lower.

g. Zinc (Zn): Recent work on seedlings of 'Keaau' (660) and 'Pahala' (788) suggests that leaf zinc >30 ppm is adequate, with symptoms appearing slowly at 17 ppm. In bearing trees 15- 20 has been considered adequate in the past.

h. Boron (B): Recent work on seedlings of 'Keaau' (660) and 'Pahala' (788) suggests that leaf B should be > 50, in bearing trees 75 ppm B has been recommended in the past. Deficiency symptoms are apparent at < 15 ppm B.

i. Copper (Cu): Recent work on seedlings of 'Keaau' (660) and 'Pahala' (788) suggests that 11 ppm leaf copper is adequate. Deficiency symptoms were very slow to appear. In bearing trees 4 ppm Cu has been recommended in the past.

j. Manganese (Mn): Recent work on seedlings of 'Keaau' (660) and 'Pahala' (788) suggests that 48 ppm Mn leaf is adequate, with deficiency symptoms manifested at 25 ppm Mn. In bearing trees 100 ppm Mn has been recommended in the past.

k. Length of time to express deficiency symptoms when a single nutrient has been totally withheld from 8 months old seedlings is shown:

Nutrient	Months to Visual symptoms	appearance of Reduction in growth
N	2	4
P	2	3
K	3	4
Ca	4	7
Mg	5	none after 26 months
Fe	6	12
Zn	12	15
B	8	13
Cu	15	none after 26 months
Mn	11	none after 26 months

- Leaf and soil analysis services are available from several private laboratories and the Agricultural Diagnostic Service Center (ADSC), CTAHR at cost. Grower use of the ADSC increased 125% and 37% for tissue (345 samples) and soil (272 samples) analysis, respectively, from 1985 to 1986. The number of samples received by August in 1987 was 56 and 61, tissue and soil, respectively. This appears to indicate a greater need to demonstrate the cost effectiveness of these diagnostic services to smaller growers.
- Field experimentation is insufficient for precise correlating, tissue, and soil analysis results.
- No significant results have been obtained from two earlier field two experiments that have been conducted on the effect of minor elements on yield. One experiment was conducted in Mac Farms of Hawaii's orchard, and the other was conducted in Keaau.
- The soil need not be monitored as frequently once classification and initial nutrient status is assayed. Occasional check of soil pH might be worthwhile especially in areas with high aluminium and/or manganese and low pH < 5.0.

Rx for Undernourished Macadamia Nut Trees

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Harvesting

The main harvest period for macadamia extends from August through January. In some areas, nuts mature throughout the year. Nuts fall to the ground and can be gathered by hand. Pickup should be within a month, sooner if conditions of high rainfall, rat or pig-damage are likely. Nuts should not be stored in the husk.

Most growers then sell their nuts in husk to processor, for husking, drying and cracking.

Mechanized Harvesting

- Formerly, large growers such as Mauna Loa and MacFarms used either shake harvesting or mechanical sweepers for nut harvesting. Manual pickup is generally used to harvest low density nuts on the ground in the early or late season. Shake harvesting was discontinued at MacFarms due tree injury and longer harvest season which resulted in smaller percentage of mature nuts at any harvest date. A shake harvester cost approximately $40,000 to $50,000 and can harvest approximately 200 acres.

  The harvesting acreage could be increased significantly if an economical and reliable nut ripening monitoring process could be developed and tree injury reduced. Increased harvesting area per shaker would certainly bring harvesting cost down.

- MacFarms has a contract with a mainland company to develop a vacuum harvester. Testing should begin in the 1987 season; a joint venture with Mauna Loa is being discussed. The harvester would be used in conjunction with an as yet untested system utilizing moving, rock crusher and replacement of husks on the orchard floor to decrease roughness and improve water and nutrient holding capacity.

- A small harvester developed by CTAHR is currently mounted on a 16 hp 316 John Deere tractor powered by an auxiliary 25 hp engine tandem-mounted for hydraulics. When used commercially, it should be mounted on at least a 45 hp tractor with PTO. Testing at CTAHR's Waimanalo farm in the 1986 season, the achieved harvesting rates of 200 lbs/hr (in husk) including time for off-loading nuts and fueling. Assuming the harvester has > 50% pick up efficiency and hand harvesting of 50 lbs/hr, it should reduce picker labor by 90%. The harvesting swath is 8 feet. Leaves and other trash are separated from the nuts, and shredded, new shredding device is being developed.

  Further information on this experimental harvester for manufacturing and extension is available from Dr. Tung Liang (tliang@hawaii.edu), Biosystems Engineering Department, Univ. of Hawaii, Honolulu, HI 96822. Estimated cost is $15,000 without the tractor.

- An Biosystems Engineering Master's thesis was written on hard surface roughness in terms of harvesting efficiency. Copy in the UH Hamilton Library, Daniel Paquin (1984) (paquin@hawaii.edu).

- The need for proper land preparation to facilitate mechanical harvesting is understood by the industry.

- Ethephon (Ethrel) is cleared for use to enhance nut drop (abscission). Field research on 333 indicates that application of ethephon at 400 to 500 ppm should be timed 26 to 33 weeks have maximum flowering to achieve the most rapid and complete response. Yield 1 to 3 weeks after treatment was increased, but total yield (5 weeks after treatment) was not different from the unsprayed trees. However some defoliation of the older leaves is likely (Nagao, 1986, Proc. HMNA) (mnagao@hawaii.edu). Field research is continuing.

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Industrial Organization

- The **Hawaii Macadamia Nut Association** (formerly Hawaii Macadamia Producers Association) has been serving growers and processors in the state for over 27 years.

- An interested person can join, though emphasis is on commercial growers and processors in Hawaii.

- Current membership is over than 200.

- The board of directors has 18 members representing growers from different islands and districts of Big Hawaii such as Hilo Macadamia Producers, Kohala Macadamia Growers, Kona Farmers Coop, Pacific Cofffee Coop, processors and production/processing corporations. Board members remain on the board for long periods. Officers are nominated from the board by a combination of geographic rotation and nominating committee. Election is finalized by a voice vote at the annual general membership meeting.

- The annual meeting serves to conduct HMNA's general membership business and as an educational meeting. Speakers are generally CTAHR scientists presenting research reports, innovative growers, DOA officials, and officers of the major corporate farms.

- There two large production/processing corporations--Mauna Loa, a subsidiary of C. Brewer Co., and MacFarms, with orchards over several thousand acres. They control more than 80% of the production. There a few corporate farms with hundreds of acres, and over 600 farms with less than a hundred acres, most less than 10.

- Currently, membership dues are set at $10 per year. In the past, various assessments were attempted to raise money to support HMNA activities and project. Assessments on acreage and production have been unsuccessful. Either corporations were assessing themselves large sums of money without equal control of HMNA policy and projects, or processors were unwilling to collect and turn over assessments from growers. Due to the vast differences in size small growers have been reluctant to what pay what some consider substantial sums as well.

- For a number of years Mr.'Porky' Oka served as staff member to the HMNA. He has since retired, and no staff have been hired. Without a full time staff member it is impossible to oversee any of projects, meet service goals assigned by its members, and hold an annual education meeting.
- For the HMNA to meet its responsibilities leading diversified agriculture industry in the state, it must have at least one fulltime director with managerial skills and vision and an annual budget of at least $100,000.

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Land

The following set of environmental conditions fall within the acceptable range for macadamia production:

1. Soil: well-drained a'a lava land that is sufficiently developed or weathered to support a solid cover of natural vegetation, or other deep, well-drained soil with pH range between 5.5 and 6.5.
2. Rainfall: 60 to 120 inches a year; 80 inches or more for lava land.
3. Elevation: Sea level to 2,500 feet.

- The Hawaii Natural Resource Information System (HNRIS), a computerized geographical information system, has been developed by CTAHR which catalogs land, soil, and climate information. Information can be retrieved for land use such as macadamia production.
    - An inventory of agricultural land (Hawaii island only), identifying suitable macadamia nut land, has been completed using this system. The successful development of a production function that predicts macadamia nut yield based on the environmental factors and soils of the land has made the inventory possible. The availability of a computerized database capable of supplying the needed environmental and soil characteristics of large areas of land has drastically reduced the inventory cost. The inventory is displayed in map form for reference.
    - The production function was derived by using yield data from experimental plots maintained under management conditions which may differ from those of industry. Therefore, the yield potential displayed in the maps should be used cautiously.
    - The computerized database was derived from the records of a small number of weather stations and the Hawaii soil survey. It cannot be expected to provide precise environmental information to the production function. The yield map, therefore, should be looked upon as a guide to potential areas which warrant serious on-site study before investment.
    - A report describing the system and displaying the inventory is available. For specific information contact Dr. Tung Liang (tliang@hawaii.edu), Dept. of Biosystems Engineering, University of Hawaii, Honolulu, HI 96822.
    - A better method for land evaluation is being researched.
    - USDA-SCS has developed a macadamia nut land potential rating for most soil series found on the Big Island.

- Although Hawaii Revised Statutes Section 171-37 limits State land leases for intensive agricultural uses to 35 years, the lease term can be up to 45 years for tree-crop orchards, 55 years if extensive expenditures are required, and 75 years if the lessee is required to reside on the premises. Department of Land and Natural Resources (DLNR), Land Management Division, should be consulted as to applicability of these provisions to the development of specific macadamia orchards.
- The industry increased from 475 farms, 13,300 acres in crop (10,000 bearing) in 1980 to 645 farms, 21,300 acres in crop (14,400 bearing) in 1986. New plantings decreased to only 400 acres in 1986.
- With land leased from the State, growers may pay as low as $5-$10 per acre per year for the first few years, but will have to share a percentage of gross sales. Other land can be leased for $30 to $120 per acre per year, plus lease purchase. Fee Simple land costs between $2000 and $8000 per acre. Land with mature trees sell for $10,000 to $20,000 per acre.
- Construction of the Panaewa Agricultural Park begun in the fall of 1980 and was completed and lots were leased in December, 1981. It includes 6 lots of 20 acres in size for macadamia production, 22 lots for other orchard and nursery crops, and a 110 acre lot for the University of Hawaii at Hilo farm laboratory.

  There has been much interest expressed on the acquisition of land for macadamia. More agricultural parks are desirable; it may be the only way for many small growers to get into the business.
- Some former sugarcane lands in Honokaa, Kohala, Hilo, Kau, and Wailuku are now being used for macadamia. Macadamia may be a good alternative for other sugarcane lands that go out of production. More land (formerly under sugarcane) is being made available for macadamia expansion. New plantings are expected on Kauai.

- Soil erosion can be a problem in certain areas. Plans for land clearing must be approved by the County to insure proper erosion control is incorporated in the development of new orchards. USDA's Soil Conservation Service can assist and should ideally be consulted prior to orchard planting. Terracing and ground covers could prevent erosion (although ground covers could hinder harvesting). In mature orchards, dense canopy shade out ground cover. Growers on sloping land with soil need shade tolerant ground covers to prevent erosion after orchards have closed-in.

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Marketing

- Annual statistics on in-shell production, farm price and total sales are produced by Hawaii Macadamia Nuts, Annual Summary Hawaii Agricultural Statistics Service, (HASS) DOA, USDA cooperating. The most recent report is July 12, 1999.

  Imports of macadamia nuts into the United States as tons of kernels and value by country and by port of entry were available for the first time for calendar year 1982, compiled from U.S. Dept. Commerce data and have been published and disseminated by HASS/DOA since 1982. U.S. macadamia exports are now available in a report with the U.S. imports compiled by Dept. Commerce from the Foreign Agricultural Service. It may also be possible to obtain permission from Matson Shipping Lines to use their mainland shipments of macadamias as an indication of Hawaii exports.

- The value of the macadamia industry as other agriculture industries is grossly undervalued if only the farm value is used. Significant value is added by the time the product is sold wholesale as dry kernels, and retail as salted nuts, in candies, and other products.

  A crude estimate of the wholesale value of Hawaii-produced kernels in 1986 on 11 million pounds of kernels (assuming 25% recovery from 44 million pounds of wet in-shell nuts) was $105 million in 1986 compared to $35.2 million as farm sales). An estimated 57% was sold in Hawaii for $50 million and 43% outside the state for $54 million. The estimated value of macadamia products sold retail in Hawaii in 1986 was $66 million, two thirds as snack nuts and one third as chocolate candy. No estimates were available for the retail value of other macadamia products such as cookies, ice cream, or of macadamia products sold on the mainland or elsewhere.

  A new CTAHR project is being develop to more precisely estimate the value-added to various commodities to show show more clearly the links to employment in other industries.

- Demand is increasing for macadamia oil by the cosmetic industry, especially in Japan. MacFarms is investigating the development of a oil pressing facility to handle immature and culled nuts, brokens, and fines. Value-added is increased substantially if oil can be pressed, partially refined, and sold directly to a cosmetic company. No values are reported for the potential value for this product. A press to handle the much of the industries volume would cost $80,000. Press cake has value as an animal feed.

- According to projections made by Scott (CTAHR, 1975), a fully developed U.S. market for macadamia nuts could absorb 32.2 million lbs. of kernels by 1990.

- It is estimated that the U.S. consumption of tree nuts is now about 50% of world commercial consumption. Based on this estimate, the potential world market for macadamias would amount to 64.4 million lbs. of kernels annually. The major consumers outside of the U.S. are the Western European countries and Japan. A reasonable sales potential for Hawaii's industry might approximate the fully developed U.S. market.

- Although Hawaii is the major producer of in-shell macadamias, wholesale kernels and finished macadamia products, expanding foreign production is decreasing Hawaii's market share. The US macadamia industry, predominantly in based in Hawaii or affiliated with mainland food manufacturers, imports about 10% of its kernels to meet demand which can not be met by production in Hawaii.

  Foreign competition is not strong now, but has the potential of becoming serious. Earlier this decade the leading foreign exporters of macadamias to the US were Kenya, Republic of South Africa and Guatemala, in 1986 the exporters to the US in order of volume were Australia, Guatemala, South Africa, Costa Rica, Malawi, Zimbabwe and Brazil.

  Sources of nuts imported into the United States in millions pounds of dry kernels:

Country	1982	1983	1984	1985	1986
Australia	0.023	0	0.130	0.590	0.610
Brazil	0	0	0	0	0.030
Costa Rica	0	0	0.002	0.016	0.070
Guatemala	0.150	0.150	0.270	0.200	0.610
Kenya	0.220	0.220	0.078	0.042	0
Malawi	0	0.002	0.012	0.012	0.066
South Africa	0.140	0.120	0.380	0.510	0.340
Zimbabwe	0	0	0	0	0.004

  Production in foreign countries was discussed in several Proc. HMNA articles and most recently by Ito and Hamilton and Davis in Proc. HMNA 25 (1985), and by Vidgen in 1987 HMNA annual meeting. From Proc. HMNA 25, two articles on foreign acreage in macadamia reveal how difficult it is to estimate with any confidence. Ito and Hamilton best estimates in 1985 are presented below with the most recent US import data and Vidgen and Leeson 1987 and 2000 world production estimates.

Country	Species	Tree Age (yrs in 1985)	Tree Yield in-shell (lbs/tree) in 1985	Production Estimate (million lbs of kernels)	
1987	2000				
Australia	>90% smooth	10	15	2.2	8
Brazil	>50% rough	6	0.3	-	-
California	rough	10+	20	-	0.1
Costa Rica	smooth	9	10	0.4	6.0
Guatemala	smooth	8	8	0.3	0.4
Kenya	>85% smooth	10	0.5	0.4	0.2
Malawi	>85% smooth	7	2	0.2	0.2
S. Africa	80% smooth	7	0.7	0.5	0.5
Zimbabwe	>85% smooth	7	1	-	0.4
Hawaii	smooth	10+	64	10.7	20.0
World (total)		14.7	35.8		

- In the early 1980s, the industry faced a "soft" market and "temporary" gluts due to various reasons including the economy.

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Insect Pests In The Orchard

Pests of macadamia orchards in probable order of importance are the:

1. koa seedworm (*Cryptophlebia illepida*)
2. litchi fruit moth also called macadamia nut borer in Australia (*C. ombrodelta*)
3. southern green stinkbug (*Nezara viridula*)
4. macadamia nut borer (*Polyphagotarsonemus latus*)
5. Hawaiian flower thrips (*Thrips hawaiiensis*)
6. redbanded thrips (*Selenothrips rubrocinctus*)
7. black citrus aphid (*Toxoptera aurantii*)
8. Van Duzee treehopper (*Vanduzea segmentata*).

Koa seedworm and litchi fruit moth

Eggs are deposited on the surfaces of the husks and hatch in 3-5 days. Caterpillars tunnel immediately into the husks where they feed under the surface. Caterpillars mature in 16 days and pupate within the husk near an exit hole. An inconspicuous brown moth emerges in 8-12 days. Adults are active at night, and females can lay more than 300 eggs during their lifespan.

Recent reports from Australia indicate that *Cryptophlebia* spp. are a major pest of macadamia, in Africa, Australia (as high as 60% losses in orchards near urban areas), and Central America. In Hawaii losses were thought to occur primarily when caterpillars bore through the shells and feed on the kernels. This apparently occurs when the nut shells are rather soft because there are higher rates of damaged nuts early during the harvesting season. In other areas and most recently in Hawaii it is realized that caterpillar feeding damage in the husks can result in immature nut drop in addition to the normal June drop. In the past, some farms in Honokaa reported 15-50% losses, most recently the damage has been reported in Kona as far south as Honomalino.

MacFarms has instituted a moth trapping and nut sampling program utilizing light and pheromone traps and sampling nuts, both on trees and on the ground quantify the population. Accurate information on losses is required in order to determine whether it is economically feasible to apply controls.

Chemical control does not appear feasible because of the pest biology. Even in Australia where established monitoring methods and cypermethrin, a synthetic pyrethrin, applied with ground equipment are used, the control is only marginal. In Hawaii, registration of a new chemical and a more sprays per crop due to our longer flowering period would be necessary.

In Malawi, disrupting the mating of adults with mass aerial application of pheromone has been successful. An Australian system incorporates pheromone into a small wick and placed in tree. The wicks last up to a six months and costs 40 to 50 cents a tree. The wick and pheromone might require registration. Research to test efficacy is necessary.

Ten species of parasites were recorded for Koa sees worm in Hawaii in 1956 (Namba, *Proc. Haw Entom.* 23), but no information exists on how much control they exert. This information is needed before a decision to search for other parasites including egg parasites such as the wasp (*Trichogrammatoidea fulva*). Importation of new parasites could take more than a year, and there is no guarantee that it would establish in Hawaii.

Southern green stink bug.

This pest has a wide host range in Hawaii. Common host plants are *Crotalaria* spp., *Amaranthus* spp., *Desmodium* spp., *Asystasia* sp., and spiderweed, but many other weeds and vegetables are good hosts. Leguminous plants are commonly preferred.

Immature stages and adults have sucking mouthparts and feed on succulent plant parts as well as fruits. Stink bugs can penetrate the hard macadamia shell to feed on the kernel for a short period. Although this pest is considered a serious pest of macadamia because of the damage to nut kernels, no breeding on macadamia has been observed.

CTAHR entomologists have studied the ecology of the stink bug in commercial as well as experimental macadamia orchards. The results showed that stink bugs preferred to remain on weeds such as Crotalaria bordering the edge of orchards, and that there was no increase in nut damage despite the presence of breeding population of stink bugs on *Crotalaria* plants which were found throughout the experimental orchard.

Although stink bugs can readily be controlled using currently registered insecticides (malathion and endosulfan), application of these insecticides is normally not needed in macadamia.

Several species of parasitic insects were introduced for controlling this pest. Two of the more important are a fly parasite (*Trichopoda pennipes*) of stink bug adults and a wasp parasite (*Trissolcus basalis*) of stink bug eggs. Both parasites are very effective. The parasitic fly finds stink bugs by homing in on an odor which male bugs have. It is not known how the parasitic wasp locates stink bug egg clusters, but the wasp parasitizes all of the eggs in the cluster (80-120 eggs) which it locates. The fly parasite requires a nectar source, and it was found that *Crotalaria* is an acceptable source.

It is believed that much of current damage to nuts can be attributed to stink bugs which enter macadamia fields after certain weed host plants such as spiny amaranth die, or to the practice of utilizing stink bug hosts as ground covers. Damage can be minimized by utilizing the "trap-border" method. *Crotalaria* border plantings can be utilized to attract and hold stink bugs which would normally damage macadamia. One test reduced damaged from 16 to 3%. In this way parasites can then easily locate and control the pest. Insecticides can be applied to the borders if parasites are absent. One estimate indicated a 9% loss due to stink bug in Kona. Damage in the Hilo area is insignificant.

Recent observations suggest that stink bug adults could cause significant kernel injury.

Macadamia insects and others pests, Knowledge Master, CTAHR
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Planting

- New commercial orchards should be planned as complete production systems. Among the considerations which arise from present knowledge are:

  1. Select cultivars (varieties) which tend towards a short bearing season.
  2. Recent studies by Ito and Hamiltion (CTAHR) showed that yields of "Keauhou" from a mixed planting averaged about 16 kg (35.2 lbs.) more per tree than from a pure block planting. Mixed orchard nuts were larger, had more kernels and more oil. Consideration needs to be given to include selections known to be good pollinators within each field.
  3. Use cultivars which have an upright growth habit and can be grown close together. Consider planting closer in rows while leaving sufficient space between rows for spraying and harvesting equipment.
  4. Use cultivars which have a high proportion of No. 1 nuts, thin shells, and other desirable characteristics.

  Checking with your county agent and most importantly with growers nearby will help you in deciding what will succeed in your particular area.

- A survey by Keeler (CTAHR) showed extreme variation in yield ranging from as high as 300 lbs. in-shell nuts per tree to nil. Estimated mean yield for trees spaced 30' x 30'(48 trees per acre) is 150 lbs. per tree (7,200 lbs/acre). Yields at Keaau Orchard, for trees spaced 25' x 25' (70 trees per acre) on orchard closure and full nutrition, averaged about 100 lbs. per tree (6,970 lbs/acre). Potential yield will depend on the land quality, particularly with regard to available moisture, nutrition and also on how reliable are the projections for increased recovery.

- A figure commonly used is 5,200 lbs./acre and this may prove to be the limit for poorer lands under current technology, with 7,000 lbs./acre readily attainable on the better lands with the overall average somewhere between. The state average for bearing orchards is 3100 lbs /acre.
- Since macadamia starts producing in about six years, there is a long period of negative cash flow. To alleviate this cash flow problem somewhat, it is suggested that the initial planting density be increased from the conventional 48 trees per acre to a higher density. Since trees will be small initially, more trees can be adequately supported on one acre. If more trees are available to produce a few nuts, the total production per acre should be higher in the early years.

  As the orchard matures, a systematic program of pruning and tree removal can be initiated so that the per acre yield will be unchanged from the conventional planting density of 48 trees per acre. The industry is trying densities of 70 and 95 trees per acre. High density plantings look promising. Higher yields per acre are being realized. High density planting depends on low cost trees for planting.

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Processing

- Increasing the kernel recovery rate from in-shell nuts is important. However, this must be balanced against increased cost of improved recovery. Recovery is not important per se, but cost of producing a unit weight of kernel is. Improved recovery does not necessarily mean lower cost.
- Improved processing systems with better shell-kernel separators and better cracking method could increase the kernel recovery rate to 35%. Recovery rate also depends on variety and moisture level. Nuts sold by the farmer average 16% moisture or more. The current drying process produces kernels with less than 1.5% moisture. Drier nuts ar much more susceptible to mechanical damage more bits and chips and hence lower recovery, therefore careful handling and transport during and after drying is critical, (Cavaletto, 1986, Proc. HMNA 26). However more research is needed damage occurring to nuts in-shell and after cracking.
- The current estimated kernel recovery rate is greater than 23% based on final product and 28% based on bulk kernel sales as nuts from new cultivars beginning enter production. Processing technology to increase the recovery rate to about 31% is available.
- Insect infestation of stored kernels is a problem for some processors (Mitchell, 1985, Proc. HMNA 25). There is a need to look into the threat of stored kernel insect pests being brought into the State with the importation of nuts from overseas. Current DOA/PQ and USDA regulations need to be reviewed. DOA/PQ currently has no inspection, treatment or certification program for nuts or kernels imported for processing. Mauna Loa freezes imported kernels in their containers on the mainland prior to shipment to Hawaii.
- The industry sporadically experiences a kernel bruise-browning problem. A CTAHR project supported by Hatch funds revealed that the problem involves mechanical damage to in-shell nuts at intermediate moisture content. It appears most serious on the cultivar 508 when the in-shell moisture content is between 10 and 14%. Cultivar differences are likely.
- Harvest interval (the time the nuts are left on the ground) affects shelf-life of the final product. A study conducted by industry found that after 6 weeks, quality and shelf-life decreases. Maturity did affect shelf-life, although it affected quality. A CTAHR project funded by a USDA section 406 grant which ends in 1988, is examining this problem in greater depth.
- A great deal is known about quality control on the farm, but the necessary measures are not always practiced. A special workshop was organized for Kona growers in 1986 by CTAHR's Cooperative Extension Service and HMNA to discuss growers' practices. However, it is up to the grower to put these quality control measures into practice.
- Several small, locally developed processing systems are available and in use. These make small farms more profitable, but the overall net impact these systems will have on the industry is unknown. There may be more variation in kernel quality with many small processors. Also, competition for the same markets may start to occur because there will be more people marketing kernels.
- CTAHR designed and constructed prototype macadamia nut cracker capable of producing the optimal deformation on all sizes of macadamia nut. This project funded by regional Hatch funds has made progress in fracture control and flash drying to attain optimum kernel and shell moisture to increase kernel recovery (Liang, 1984, Proc. HMNA 24.)

  The important feature of the cracker is that the orientation of the nut during sizing is maintained during the cracking operation. Recent research examined the role of shell notching and freezing on recovery of whole kernels. Notching reduced the force and the deformation required to achieve whole kernel recovery. Percentage recovery as whole kernels increased from 28 to 42%, and percentage of uncracked nuts decreased 14 to 6%.

  Freezing increased whole kernel recovery from 28 to 83%, half kernels were reduced from 46 to 7%, and uncracked nuts from 14 to 10%. Combining both processes increased whole kernel recovery from 28 to 88%, reduced half kernels from 46 to 9%, and decreased uncracked nuts from 14 to 2%. At the scale of the pilot operation, the increase in energy consumption was offset by the increased value as whole kernels (Jason C.S. Chon, 1987, M.S. thesis, Dept. of Biosystems Engineering, CTAHR).

A semi-continuous deep bed drying process of in-shell macadamia nuts was further enhanced for industry adoption by the completion of research for a M.S.thesis in Biosystems Engineering (CTAHR) by Suhas Mehra (undefended as of May, 1987). The technique could dry nuts to a uniform desired moisture content independent of bed cross-section area, and can potentially be completely automated. Estimation of total timing time for a given lot can be accurately estimated after ten hours of drying.

- Floatation separation using water or brine is used by several processors to separate highest quality kernels from lower quality kernels and shell pieces. A dry kernel and shell separation method is desirable to increase of processing, however funds are lacking for this.
- Extent of losses from the stuck-kernel problem is unknown. This affects the recovery rate and appearance of the end product. A few current cultivars have been examined for kernel sticking and some differences were observed.
- Rancid nuts cannot be identified visually, and analytical methods have not been sensitive enough to detect early signs during processing. A CTAHR project funded by a USDA 406 grant which unfortunately expires this year has made significant progress in acquiring the equipment and developing the necessary methodology to detect the problem at early stages.

  While it is apparent that tocopherol, a well-known antioxidant is present in only low levels in macadamia, other potent antioxidants have been identified and appear to vary by cultivar. An assessment of reduction in shelf-life as a result of field and processing practices has begun under this project. This importance of this research increases if the industry were to enter a period of high inventory and low price brought about by increased production. Additional funding will be necessary to complete this promising research.
- Demand is increasing for macadamia oil by the cosmetic industry, especially in Japan. MacFarms is investigating the development of a oil pressing facility to handle immature and culled nuts, brokens, and fines. Value-added is increased substantially if oil can be pressed, partially refined and sold directly to a cosmetic company. The press cake would have value as animal feed.
- Amendments to Chapter 4-44, Administrative Rules, "Standards for Fresh Fruits and Vegetables" and Chapter 4-44, Administrative Rules, "Standards for Processed Products" became effective August 18, 1983. These amendments were developed in cooperation with the Macadamia Nut Industry Standards Committee and brought the standards for the in-shell, shelled and roasted macadamia nuts up to current market requirements. Subsequent to these amendments, the industry requested that consumer grades for in-shell and shelled macadamia nuts be established. The consumer grades became effective January 16, 1984.
- The grading procedures for shelled and in-shell macadamia nuts will be further refined in April 1987 and all inspectors trained in the new procedures in Fiscal Year 1986-87. The grading procedures for roasted macadamia nuts will be further refined in Fiscal Year 1987-88 followed by training of all inspectors.
- Moisture balances are now available in both East and West Hawaii districts. Effective January 1,1984, the Kona Coffee Technician has been upgraded to an Agricultural Commodities Aid II whose duties include macadamia nut certification and enforcement. The program's proposed Fiscal Year 1988-1989 budget include funding for an additional Agricultural Commodities Marketing Specialist for Kona.
- Consumers perceive that some manufacturers intentionally or unintentionally deceive the public by implying that a product contains more macadamia nuts than is actually present or that the shape of the package implies more product for less cost.

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Propagation

Large commercial fruit nurseries are uncommon in Hawaii owing to relatively small size of our industries and longevity of crops. However in most areas there are nurserymen who will do contract propagtion. Check with neighbor growers, HMNA representative, or extension agent.

Remember, grafted macadamia do not ship well. Survival after an interisland journey may not be satisfactory.

Actual experience with macadamias is usually essential for grafting success because the wood is exceptionally hard and brittle. Scion-wood should be girdled at least 5 weeks in advance to accumulate starch a for successful grafts. Whether or not sufficient time has elapsed can be tested by observing if a strong starch (blue-black color) reaction occurs when dilute tincture of iodine or water solution of potassium iodide is applied to a freshly cut surface of the scion wood above the girdle. Without sufficient starch reserves, the graft will not take.

- Work is needed to develop more asexual propagation methods for macadamia. Some work done in Hawaii and Rhodesia has shown that macadamia cuttings can be made to root. The results of the work done in Hawaii have not been published. However, the root system of trees propagated in this way are weak and susceptible to blow-downs. This has been shown in a test planting at Keaau Orchard and an experiment at Waiakea (unpublished). Seedling rootstocks were always more vigorous than the rooted cuttings tried.
- Experimentation on the mass propagation of desirable cultivars by tissue culture was conducted by T. Matsumoto Nursery. This research was funded by the Dept. of Research and Development, County of Hawaii and HMNA. The culturing was successful, but plants have not been established under field conditions yet. However, the economics of this method over the present method of grafting is still under investigation.
- Research in Israel demonstrates that macadamia can be propagated from air layers. Plants propagated in this manner bearing several years earlier that grafted plants. Resistance to wind damage has not been determined in Israel. A field experiment is underway to air layer plants in Hawaii and to determine its potential.

- Do not use trees on rough-shell (tetraphylla rootstocks). Rough-shell seedlings are sometimes preferred by nurserymen because they germinate uniformly, grow faster and more uniformly in the nursery, and are considered somewhat easier to graft and transplant. However, the trunk of smooth-shell varieties sometimes grows faster and increases in diameter more rapidly than the rough-shell rootstock. When this occurs, the trunk just above the graft union becomes larger and thicker than the rootstock section below the graft union. This problem, known as scion overgrowth, is considered undesirable in orchard trees and should be avoided. Fortunately, it rarely occurs when smooth-shell varieties are grafted on smooth-shell seedling.
- Punch budding is a propagation technique used in Australia which appears to be more efficient than the wedge-grafting technique used in Hawaii. Less scionwood is required in punch budding, which is a major advantage when trying to propagate large quantities of limited materials. Preliminary trials on punch budding in Hawaii gave less than satisfactory results.

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Pruning

Pruning is essentially limited to developing a conical tree shape with strong scaffold limbs in the first two years following transplanting in the orchard. The reason for pruning is to encourage maximium production and reduce susceptibility to wind damage. The objective is to leave three branches at a node (whorl) with wide angles from a single leader. Another whorl of 3 branches should be left one and half to two feet above, so that these do not interfere with the branches below. Some cultivars like 344 and 660 produce this shape with little pruning.

If too many branches emerge at a whorl, prune (thin out) to three.

If two or more vertical stems (leaders) are present, prune to only one.

If a young tree produces only vertical growth without branching, prune (head back) at 3 to 4 feet, select a new vertical bracnch as the leader, and prune others to leave 3 branches with wide angles as scaffolds.

If root or trunk suckers grow from the rootstock, remove them.

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Public Policies and Regulations

- OSHA, EPA, etc., have many policies and regulations that affect the macadamia nut industry. The public policies and regulations that affect the industry should be complied and updated periodically. Policies affecting importation of agricultural commodities affecting marketing competition would be monitored by DOA Marketing and Consumer Services Division. Importation of insect or disease contaminated produce would fall under the jurisdiction of the USDA and/or DOA Plant Quarantine Branch of the Plant Industry Division.
- The industry is concerned that the importation of macadamia plants, and nuts for planting and nuts for processing lead to the introduction of macadamia pests to Hawaii.
- Current DOA/PQ and USDA regulations need to be reviewed, as no special regulations exist regarding importation of macadamia plants or seed. DOA/PQ merely requires inspection of macadamia materials imported for planting. Regulations are also lacking for nuts or kernels imported for processing. As a precaution against importing pests, Mauna Loa freezes imported kernels on the mainland prior to shipping them to Hawaii.
- All pesticides are coming under close scrutiny by regulatory agencies. Two pesticides registered for macadamia though infrequently used, Difolatan and Plictran, fungicide and miticide respectively, have been banned. Atrazine, a commonly used preemergence herbicide, may be banned. Agricultural organizations individually and collectively must work to maintain a public dialogue on pesticide use. Laws governing the use of pesticides should be based on a rational approach and cost/budget ratios. A crop loss assessment program is one approach that can be initiated to examine damage and to determine economic value of losses address these issues and to develop feasible and socially acceptable solutions.

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Water

- If macadamia is grown on porous a'a type soil, at least 80-100 inches of rainfall is required.
- If macadamia is grown on soil, at least 60 inches of rainfall is required.

- If rainfall is insufficient, irrigation would be required. Whether macadamia is grown in regular soil or a'a type soil, the trees should receive about 0.20 inch of water per day from rainfall and/or irrigation (5,500 gal./acre/day).
- Lack of adequate water is depressing growth and yield in some areas, particularly south Kona. These areas would benefit greatly if water sources were developed to allow irrigation.
- Mauna Loa Macadamia Nut Corporation is developing its own water sources and irrigation facilities in Kau.
- In Kona, growers who use municipal water for irrigation have to pay $0.65 per 1,000 gal. This rate is based on agricultural use.
- The State has recently completed the drilling and testing of an exploratory well on State land in South Kona near Honomalino at an elevation of 849 feet. Results indicate the well can produce 750 gallons per minute of brackish water (800 ppm chloride). A great deal of the arid, low elevation belt of the Big Island has ground water that is not potable, but may be sufficient quality for irrigation. There are large abandoned areas in Honomalino which may be revived by irrigation.

  CTAHR and Farms of Kapua are cooperating to determine the field tolerance to salinity of the cultivars '344' and '800'. Trees are grown under an irrigation scheme with rainfall only, and water concentrations of 0, 500, and 1200 ppm salt applied at a rate of 80% of rainfall-adjusted evapotranspiration.
- MacFarms plans to drill a well mauka of the State well in Honomalino to irrigate its lower orchards.
- A cooperative irrigation experiment between Mac Farms of Hawaii and CTAHR was conducted on Mac Farms' orchard, and the results report by Foss (1986, Proc. HMNA 26). The experiment was installed in an area (lower elevation) which receives insufficient rainfall. Water is being applied through a micro-jet system at 6 different rates (4, 8, 12, 16, 20, and 24 gals. per tree per day) with adjustments being made for rainfall. Average cumulative yield increase over unirrigated trees for two cultivars over 6 years at 1200' altitude was almost 60%. At 1700' (higher rainfall) the yield improvement was 8 to 10%. Effects of irrigation was reduced premature nut drop and greater tree growth and hence bearing surface.
- The Hamakua agricultural water study, which commenced in 1979, is now completed. The study:
  1. Identified the agricultural water and related land resource problems and concerns.
  2. Inventoried the study area's resource base.
  3. Developed and evaluated alternative plans for alleviating the agricultural water and related land resource problems.
  4. Selected a preferred plan.
  5. Identified technical and financial assistance opportunities through federal, state, and local agencies for implementation of the preferred plan.

  USDA-SCS can be contacted for details.
- If irrigation water is required, macadamia should be grown where water is available or where the cost of pumping water will not be prohibitive. Wells in many areas have highly saline water.
- If 60 inches of rain is adequate to support a crop, 30 inches of rainfall can support a field with half the number of trees if water from the entire area is concentrated in half the area. The region between Hawi and Mahukona is an ideal place to test the idea of catchment irrigation. The region between Mahukona and Kawaihae at elevations between 500 and 1,500 feet may also be suitable for this type of farming.

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