breadfruit is usually baked or steamed.

When the green mature fruit is boiled, it resembles potato in flavor. Green mature breadfruit can simply be diced and, as is done with potatoes, added to chowder.

Steaming is a method particularly suited to preparation of green mature breadfruit. To steam, remove the stem and core (and the rind, if desired); cut into halves or quarters and steam in a covered pan until thoroughly cooked (one to two hours). Season with salt and pepper and dot with margarine.

For baking, select a breadfruit with rind that is partially brown. Remove stem and core, and place breadfruit in a pan with a small amount of water. Bake at 350° F. for an hour, or until tender.

Very ripe uncooked breadfruit was used by the old Hawaiians for a pudding. The breadfruit was mashed, mixed with coconut milk, wrapped in ti leaves and baked. This pudding was eaten as such, or sliced and dried in the sun for later use. To preserve it until the next crop, it was occasionally placed in the sun to prevent mildew.

Today in Hawaii, baked or steamed breadfruit is often served as a vegetable in a gourmet dinner.

The Polynesian Voyaging Society, as part of the Bicentennial celebration, is going on a month-and-a-half voyage from Oahu to Tahiti in March or April 1976. One of the food items they will carry is breadfruit. They are now experimenting on how best to preserve breadfruit by drying, baking, and wrapping – all methods of preservation now being used in Micronesia and Malaysia.

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Macadamia Nut Production in Hawaii

HIROSHI OOKA[1]

Macadamia nut production in Hawaii will be reviewed with operations and problems encountered at Brewer Orchards on the island of Hawaii where about 4,030 acres are under cultivation at two separate locations.

Macadamia Statistics

According to the 1974 statistics of Hawaiian Agriculture, there were 350 farms growing macadamia nuts each with an annual sales of $600 or more. The total state acreage in crop was 9,890 of which 5,760 acres were bearing. 18,750,000 lbs. of in-shell nuts were sold at 29 cents per lb. for a total of $3,986,000. It is interesting to note that 9,840 acres were planted on the island of Hawaii or 99.5% of the total. Brewer Orchards grows over 4,000 acres or 41% of the acreage on the island of Hawaii.

The macadamia nut was introduced into Hawaii from Australia in the 1800's. Interest in its culture had its ups and downs since 1920 when the first commercial venture was started. When the virtues of the processed macadamia nuts became better known by 1947, Castle and Cooke, Inc. be-

[1]Brewer Orchards, Inc., Hilo, Hawaii.

gan the development of a 1,000 acre macadamia orchard near Hilo in 1948.

The industry is based on the "smooth-shell" macadamia nut, *Macadamia integrifolia.* Hawaiian clonal varieties 'Keahou', 'Kakea', 'Ikaika', 'Keaau', and 'Ka'u' (Figure 1) are the backbone of the industry today. The last two varieties were named after our two orchards where the clones were evaluated. Promising clones are continuously being evaluated in cooperation with the Horticulture Department of the Hawaii Agricultural Experiment Station for future release.

Our orchard near the city of Hilo was started in 1948 when the typical Hawaiian forests rising from the base of an ancient lava flow were cleared with bulldozers, levelled, and rolled for planting.

The land is typical histosol or tropofolist. Macadamia nut trees grow well in fragmental Aa lava if well fertilized and provided with adequate moisture.

Figure 1: Variety Ka'u.

Nursery

Even before clearing began, a nursery was started and seed nuts planted. In about two months, the seeds germinate and the small seedlings are transplanted in gallon size plastic bags. Rigid culling of the seedlings is practiced to eliminate those with poor primary root structures. The rootstock of smooth or rough shell varieties are grown for a year before grafting. The desirable scionwood are girdled about a month or two before grafting to allow for a buildup of starches. Graft takes are enhanced by girdling. The side wedge graft is commonly used in Hawaii.

Planting

The young trees are normally planted in the field a year after grafting. Planting trees a year older has its advantages in mechanized culture.

A beefed-up hole digging auger was used to dig holes in our first 1,000 acres. A backhoe was used to dig holes in our recent plantings of about 1,500 acres.

Trees in our first planting were spaced 25 ft. x 25 ft. or 70 trees per acre. The recent plantings were of a higher density or 95 trees to an acre with trees planted 30 ft. by 30 ft. with one tree in the center.

Soil is shovelled into the holes and phosphate fertilizer added before placing the trees and covering with more soil. In our recent planting, the backhoe dug deeper, wider holes, but dug up more large rocks which created a removal problem. However, these holes made for better tree growth. As formerly, soil was added to the bottom of the holes and the trees placed on top, more soil added and tempered. Three compressed, slow release fertilizer pills about 21 grams each with a 28-10-5 formulation were added. This fertilization held up for two years. For the next two

years, these trees will be fertilized by hand or machine.

Young Tree Care

Young tree care consists mainly of pruning to properly shape the tree to a central leader with wide angled branches. The macadamia tree produces much sucker growth which must be removed from time to time to balance the tree. As the tree gets older, branches that interfere with cultural and harvesting operations are removed.

Yields

About 70 percent of our varietal trees normally come into bearing at 5 years after planting in the field. A commercial crop is expected in the seventh year when trees may produce 8 to 40 pounds of in-shell nuts per tree per year. Yields of 100 lbs. of in-shell nuts per tree per year may be obtained in the 11th year and as high as 150 pounds in the 20th year. An average of 6,000 to 7,000 lbs. of in-shell nuts per acre is possible at tree maturity. Of course, yields vary by varieties, tree size, environmental factors, cultural methods, etc.

Flowering

At our orchard at Keaau, early light flowering starts in November and peaks in February and March of the following year. (Figure 2). As the nuts mature in about 212 days, harvesting may start in late July or early August and the following March or April. When nuts mature, they drop from the trees.

Harvesting

Most of the orchard at Keaau is machine harvested off the ground using a series of three machines, blower, sweeper, nut pick up. These machines are beefed-up nut harvesting machines to stand our terrain and long harvest season. A self propelled blower of our own design and make, blows the leaves and nuts away from

Figure 2: Macadamia Flower at anthesis, nutlets, and maturing nuts.

the tree trunk area. The rubber fingered machine sweeps the nuts into windrows in the center between two rows of trees. The nut pick-up machines harvest the windrowed nuts and convey them to an attached trailer. These trailers are delivered to our processing plant for husking, drying, cracking, cooking, and packing. Five to six harvest rounds are made each year.

Shake harvesting is being perfected at our other orchard at Kau. One or two shakes are anticipated to remove most of the crop. Some hand harvesting is done in rough areas and in gleaning after mechanical harvesting. Of course, all small growers hand harvest their nuts. Some of our rough fields are being net harvested. Nuts and leaves fall onto the nets and into collection pouches. These pouches are emptied into a machine which strips the leaves and conveys the nuts

into a holding area to be later conveyed into a trailer to be hauled to the husking station.

Processing

The in-shell nuts are dried to 1.5% moisture in a series of tanks before cracking and sent to machines adjusted to the different sizes. The smooth hard nuts are cracked open by counter rotating rollers adjusted for the different sized nuts, (Figure 3).

The cracked nuts are separated from the shells and passed through a series of electronic equipment for quality selection before cooking.

The nuts are cooked in coconut oil. The excess oil is centrifuged off, and the nuts are cooled, and sent through another series of electronic machinery and trained quality inspectors to assure excellent quality of nuts.

The nuts are salted and vacuum packed in cans, glass jars, and tetrahedron pouches.

Some nuts are used in brittle. Many candy, bakery and ice cream manufacturers add the macadamia nuts in bits to a variety of products. Macadamia nuts in ice cream and chocolate covered nut clusters are two popular products.

Some Problems

The macadamia industry in Hawaii has been beset with many problems since 1920 when the first commercial venture was started. From the start, Brewer Orchards at Keaau had its share. Clearing the tropical jungle and preparing the ground for planting was truly a farmer's nightmare.

As macadamia nuts fall naturally after maturity, one of the big problems was to prevent nuts from falling in holes between the loose rocks. All fields were surfaced with volcanic ash screened to one-half inch minus to facilitate harvesting, especially mechanically. This material was

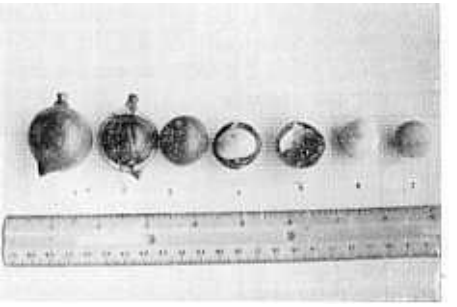

Figure 3: (1) In-husk Nut, (2) In-shell Nut exposed, (3) In-shell Nut, (4)(5) Cracked Nut, (6)(7) Kernels.

hauled from 26 miles away and required about three years to complete the job of surfacing the orchard.

About three years ago, we cleared another 1500 acres adjoining the first orchard, using the same technique of clearing, levelling, rolling, and compacting the ground with bigger and better machines. Holes were dug with a backhoe. Bigger, deeper, and better holes were made by the backhoes, but rock removal became a problem as the machine dug them up.

Nutrition has been our greatest problem. Our fertilizer practices are based on leaf analysis primarily. Leaf samples are taken two months before fertilizer application from established leaf log stations and analyzed for all macro and micro-nutrients. We may also take leaf samples from problem areas every month.

Here at Keaau, we apply fertilizer four times a year on a quarterly basis. The fertilizer is bought in bulk and stored at our airstrip. An aerial contractor applies our fertilizer as needed. We have applied over 124,000 lbs. of fertilizer in a single day requiring over 100 touchdowns by the pilot.

Because the macadamia is a shallow rooted plant and needs to be protected from the wind, Norfolk Island pine trees border the orchard fields to act as *windbreaks.*

Some trees were *in-arched* with seedlings to naturally brace them and give them added root systems for better nutrient uptake.

Mechanically applied *herbicides* combat weed growth in the orchard. This orchard helped to clear all herbicides such as atrazine, simazine, dalapon, karmex, and paraquat, currently being used in the industry. Depending on the weed species to control, these herbicides are used singly or in combinations. Because of our manner of harvesting off the ground, we need a clear orchard floor at Keaau. Strip spraying is practiced at our other orchard at Ka'u as a sod strip is needed to prevent erosion by heavy rainfall on many of their steep slopes. This area is mowed periodically.

Many new herbicides are constantly being tested for possible use and clearance. We are presently collecting efficacy data for Roundup herbicide clearance.

Disease

Blossom blights caused by *Botryis* and *Phytopthora* are among the more serious diseases of macadamia. Two fungicides, Benlate and Difolatan, have been cleared for use. Air blast sprayers are used to apply the fungicides in a limited way. However, as speed of application is necessary, aerial application has been resorted to even if ground application is considered to have better coverage and control. Two planes at the same time have been used under emergency situations.

Insects

Aphids, thrips, and even katydids cause flower damage under certain conditions and periods. Insecticides malathion and thiodan cleared for stinkbug control may be used. Zolone insecticide is awaiting federal approval. The southern green stinkbug caused much damage to mature macadamia kernels when first introduced to the islands. However, a fly parasite was introduced that did such a wonderful job of biologically controlling the stinkbug that nut damage from this insect is nil today.

Mites

The *broadmite* is our most serious pest as it attacks our flowers in all stages of development and can seriously reduce our crop. Fortunately, sulphur controls this pest very effectively and cheaply. The spraying of sulphur to control the broad mite by air will become a standard practice. Fungicides may be added to the sulphur application if needed. Morestan miticide has been cleared and plictran has been tested for possible clearance.

Rats

Rats do much damage to the crop and their control has been difficult as no rodenticide has been cleared for in-field use in the macadamia orchard. Various rodenticides have been tested and found effective to a certain degree depending on the bait. We have tested many commercial baits and formulations without much success in the field. Other rat control methods including repellents, electronic devices, electric fences, and sound have been tried with some success.

Pigs and Cattle

Wild pigs and cattle have caused damage to young trees. It is an interesting fact that pigs will select the thinner shelled varieties to crack and eat and avoid the thick shelled ones.

Tree Dieback

Tree dieback or decline is a serious problem as the tree gets older. Nutritional deficiencies and excesses have been one of the main causes of decline. Trees are often low and below standards according to our leaf analysis in nitrogen, phosphate, and mag-

nesium. Iron chlorosis is very common. Potassium, zinc, manganese, copper and sulphur deficiencies are seldom encountered. Boron deficiency has been considered serious in the decline problem. Boron excess can be easily created.

As mentioned previously, the macadamia has a poor *root system* and much of our dieback problem could be associated with poor anatomical structure of the tree at the root zone. Contriction of the primary roots at the tree base limits the flow of nutrients resulting in a total top and root starvation of the tree. If we could induce good root development the result will be a good healthy tree.

The *pH* of the soil and the nutrition of macadamia trees have been investigated. Here at Keaau, calcium carbonate and calcium silicate have been applied to correct the pH. A pH of 5.6 to 6.0 is considered best for macadamia.

The *disease* aspect of the dieback problem has been looked at since 1954. A year ago, a root rot fungus was isolated, identified, and found pathogenic. We hope control measures will be forthcoming soon.

Growth Regulators

As previously mentioned, shake harvesting of macadamia is being perfected at our orchard at Ka'u. This method of harvesting looks most promising if we can control flowering and nut drop using growth regulators. We have been testing various growth regulators, especially Alar and Ethrel with the College of Tropical Agriculture during the last four years for flower initiation and fruit set. Nut abscission using Ethrel was found successful if the trees were not under moisture stress. Residue work with Ethrel has been completed and further testing will continue. Testing of other abscission agents are planned for the 1976-77 crop season.

Closing in Tree Care

Pruning, hedging and removing trees in our closed-in orchard are problems which we will be tackling this coming year.

Irrigation

Too much *rain* and too little rain or rains not well distributed or not falling when needed is a problem. Here at Keaau we have an average annual rainfall of 135 inches. However, much is lost through our porous, rocky soil. Supplemental irrigation has been considered for many years even at Keaau. Droughts during the critical nut development period have caused depressed yields through smaller nut size. At our orchard at Ka'u, the annual rainfall is about 60 inches and not well distributed. Here a well was drilled recently and drip irrigation installed especially in the drier sections. This system will certainly help increase yields in these dry areas by supplying sufficient moisture and enhancing the uptake of nutrients.

Pollination

Increasing yields by bee pollination has been tried over the years. A study was conducted at Keaau using metallic tags glued to the abdomen of the bees and tracking their flight range. These metal tags were picked off by magnets at the entrance of the hive. Today, as more adjoining virgin forest lands are cleared and ferel bee hives destroyed, more hives must be brought in during the flowering season.

Summary

There are other problems too numerous to mention at this time that we have encountered over the years. We anticipate more problems in the years to come and we hope to overcome our limiting factors to increase yields and profits.