

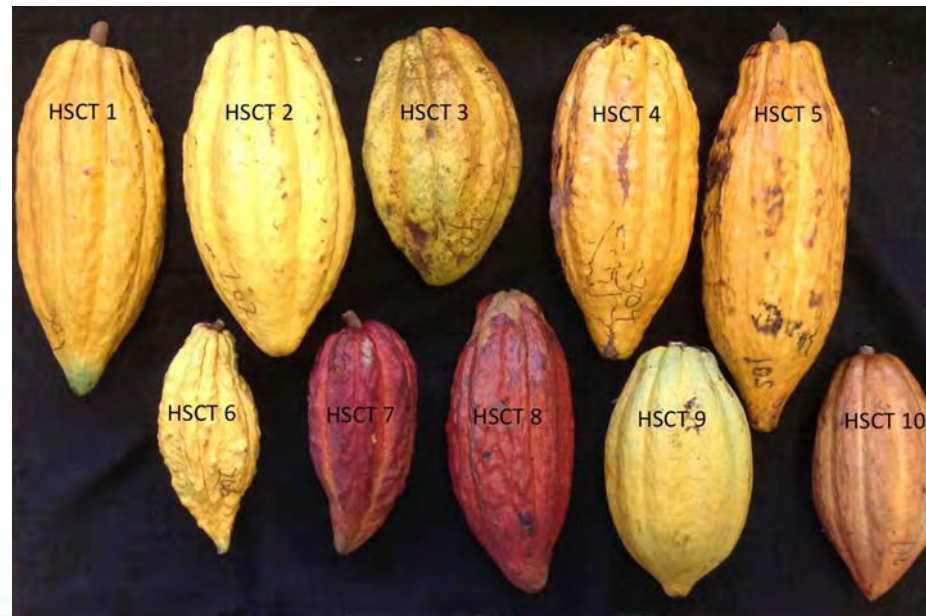
Developing Technology for Hawaii's Cacao to Chocolate Industry

HC "Skip" Bittenbender

Tropical Plant & Soil Sciences Department

CTAHR, University of Hawaii at Manoa

HCBitt@hawaii.edu



Our goal is the development of the Hawaii-grown chocolate industry based upon grafted high yield and high quality varieties.

Our motto is the world of chocolate in the islands. We propose to create these flavors by using different varieties, environments, fermentation, roasting, and blending of varieties grown in Hawaii.

Project started in 2007, funded by:

1 yr DOA Market Development grant,

1 yr DOA Tropical Fruit grant,

2 CTAHR Supplemental Research & Extension awards,

1 donation by cooperator

and my personal funds for truck mileage.



A bit of history

1831 first account of cacao (aka cocoa) was 'Guatemalan' cocoa growing in garden of Don Marin – assistant to Kamehameha I.

1850 Dr. Hillebrand re-introduced cacao in his garden (Foster Botanical Garden today).

1890s Crick and Hitchcock start orchard in Hilo.

1905 Hawaii Agricultural Experiment Station (predecessor to CTAHR) made 3 acre planting near Hilo.

1917 CTAHR reports to legislature that farms near sea level, in moist, sheltered areas of Hilo, Puna, Hana should reach 600 lb fermented and dry seed per acre.

1919 cocoa prices drop after WWI, orchards abandoned; research stops.



1956 CTAHR Dean Harold Wadsworth said,
“We know it grows in Hilo, Kona, and Hana plus no major diseases here.
Someone needs to grow 10 acres for 10 years and we’ll know if its profitable.”

1986 Jim Walsh and Hawaii Cocoa caused renewed interest when he planted imported commercial varieties near Hilo. Several international chocolate companies were potential partners. By 1992 interest waned.
Hawaii’s Industry Analysis funded projects to register the insecticide Sevin® and herbicide RoundUp® for cacao.

1988 Joe DeFrank planted seedlings purchased from Jim Walsh at the Waimanalo Research Station to register herbicides.



1997 (TPSS alum) Mike McLean with Dole obtained pods from DeFrank's Waimanalo cacao planting to establish the Dole's Waialua cacao farm from seedlings, Hawaii's largest cacao farm. Original Hawaiian Chocolate Factory in Kona begins chocolate production on a farm established by Clarence Hodge who was an contract grower for Walsh.

2004 Bittenbender attempts rooting cuttings of the Waimanalo trees.

2005 first Hawaii Cacao Symposium in Kona, a technical and informational conference. Bittenbender sends fermented seed of each Waimanalo tree for quality evaluation to Guittard Chocolate.



What technology is needed?

Varieties and propagation. All farms are growing seedlings. Cacao is mostly self-incompatible, so much tree to tree variability and potential in today's orchards.

Establishment practices. Wind breaks are needed for orchards exposed to trade winds or seasonal winds. Individual tree protection. All cacao is transplanted.

Fermentation and Drying. Hawaii is North Pole of cacao production.



10 selections for evaluation in the Hawaii State-wide Cacao Trial.

2 high percentage criollo trees from Kauai and Oahu,

2 commercial varieties Amelonado and ICS 95 recommended by USDA cocoa program in Miami,

3 Waimanalo seedlings,

2 seedlings from Waimanalo pods from the Dole cacao farm,

and 1 from the HARC Kunia collection identified by Francis Zee (USDA, Hilo).



Varieties and propagation.

Evaluated rooting cuttings:



Success was low and variable by selection. DeFrank's air layer works fine to create stock plants. Requires large diameter wood. Another vegetative method was needed.



Top wedge grafted as evaluated on different aged seedlings.

Inverted radicle grafting was encouraging; needs further development. It would nearly eliminate rootstock overgrowth. A problem in grafted cacao.



At expanded cotyledon stage.



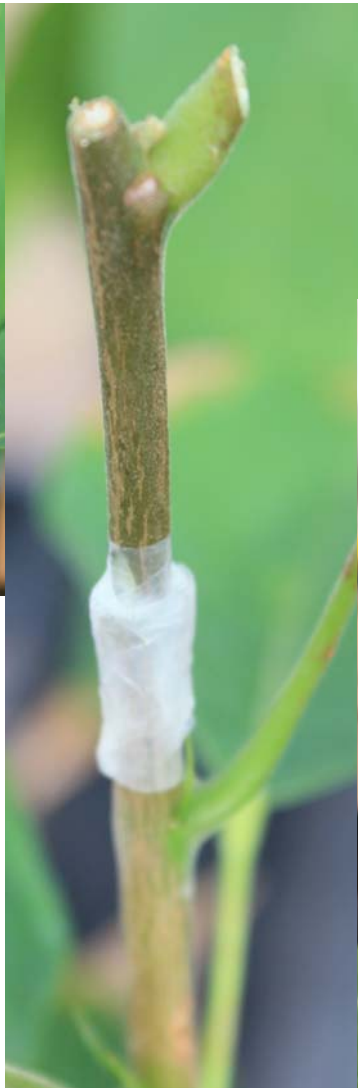
Again potential but hypocotyl splitting, and odd scion growth.



Top wedge grafting



Match scion and rootstock diameter
Wrap with Prafilm® and cover with plastic bag .



Field grafting requires cap of leaves or paper bag, then recage.



Current best practices for grafting

Rootstock seedling (remove leaves in grafting area) and scion (1- 2 buds) are same size and age-browning bark.

Cut both with razor blade, insert scion, wrap with Parafilm® grafting tape, cover tightly with Whirl-Pak® clear plastic bag. Keep warm above 80F. Shade 60-80%.

If field grafting, cover plastic bag with brown paper bag or cap of cacao leaves to create shade and not cook graft in hot clear bag in full sun. Replace field cage.

Check graft after 1 wk, remove any buds on rootstock to improve success. Once scion buds opening, loosen plastic bag and remove as leaves expand. Only remove Parafilm® if mealy bug becomes a problem.

Always remove any rootstock shoots 'chupons' to avoid rootstock over growth.





When possible use a rootstock with different color pods from scion. This helps to spot rootstock overgrowth.



Establishment Practices.

Windbreaks are essential if cacao is exposed to trade winds

Originally wiliwili haole was the intended windbreak for cacao as it was for many crops. It was killed by Erythrina gall wasp. We needed a fast, easy to propagate, locally available replacement.

I found bana grass growing at HARC in Kunia. 100 stems were taken to Waimanalo and planted to protect my cacao and kava. Bana has since been used on the farm and in cacao orchards. It is being replaced by panax – a popular long lived, garden hedge.

Madre de cacao (*Gliricidia sepium*, mother of cacao) is being tested, Dan O'Doherty found an excellent variety in Waialua that had been introduced but 'lost'.



Bana grass



Planting bana grass stems horizontally, cover 1-2 "

1 yr old bana grass



Bana grass and 2 yr old panax



As we began planting the HSCT (10 grafted selections in 4 replications) around the state, windbreaks needed to be in place. The Urban Garden Center (Pearl City) is windy, dry and hot. We chose Jim Brewbaker's KX4, sterile Leucaena for in orchard shade and over-head wind calming.

We used Joe DeFrank's large diameter, air layer technique, with great success on the KX4.





'KX4' leucaena

Cacao and KX4
sterile haole koa at
UGC, both 3 yr
old.



At 9 months

At planting





Gliricidia aka Madre de cacao

Easily
hedged or
grown
higher.

2-5 ft stakes can be planted



Seed germinate fast can
be directed seeded or
transplanted.



Intercropping is another approach



Banana and cacao
near Hilo.



Evaluating cage covers

Corrugated grow tube



Greenhouse film



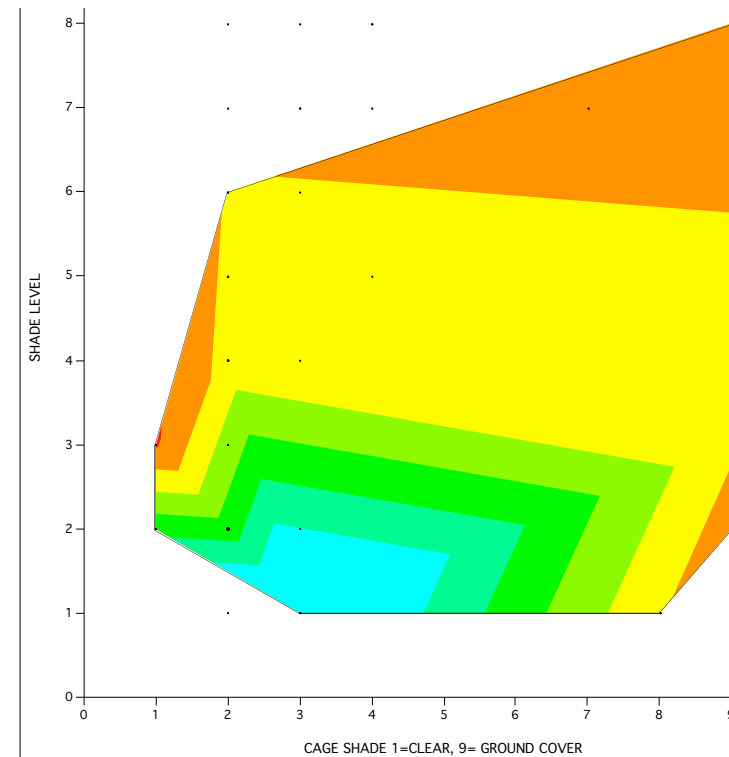
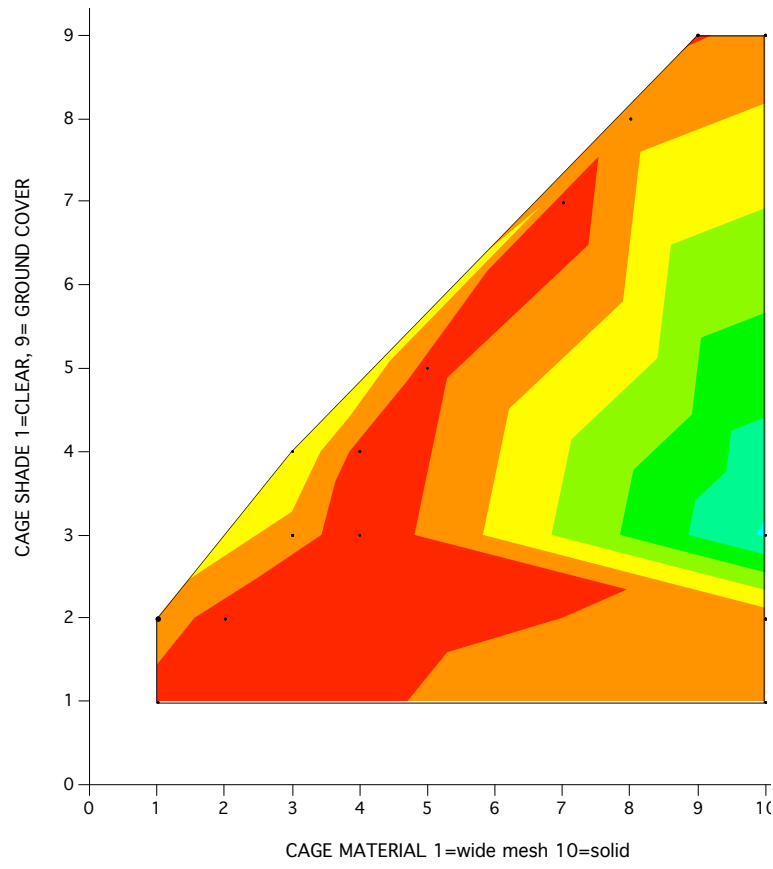
Black weed mat



30 % shade mesh



In orchard growth and vigor rating



Best growth in low orchard shade and moderate shade covering

Best growth with moderate opaque solid film or 50% shade mesh size.



Our first cage experiment at Waialua Chocolate.

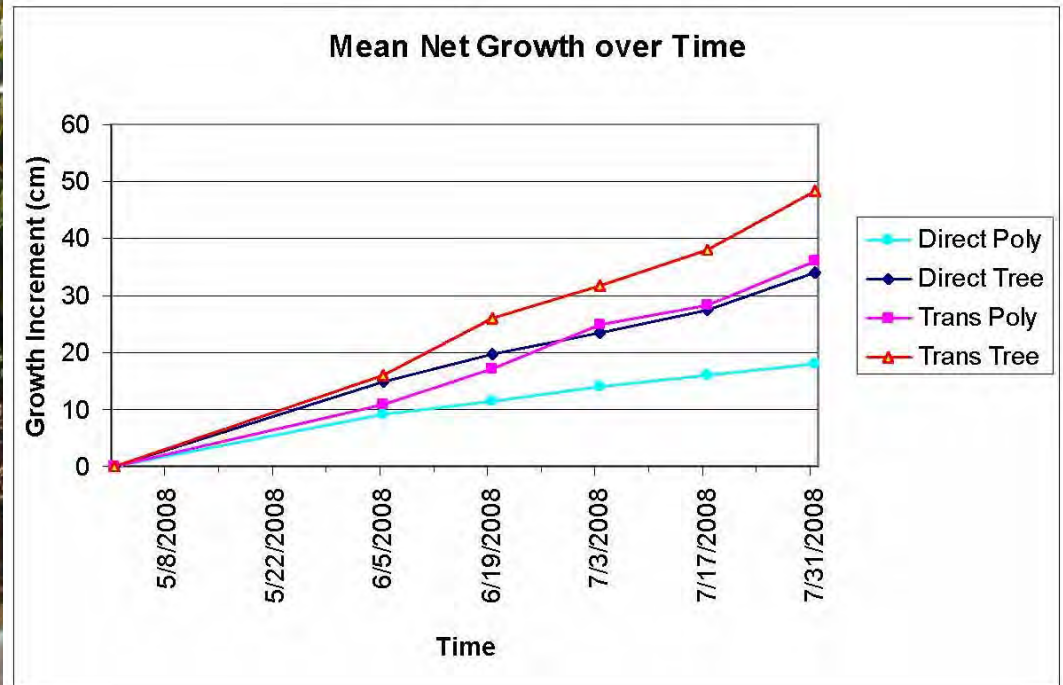
Cages are needed to protect cacao for 1 yr from direct sunlight, wind, weeds, string trimmers, Roundup® herbicide and Chinese rose beetle.

We evaluated various cage materials- varying % black shade cloth, solid translucent solids, clear and opaque films, and cage diameters from 4" to 12" and 2 to 4 ft tall.



If cages work why make seedling transplants in a nursery, why not plant the seed in the orchard?

Erik Kling compares planting seed vs. transplants in cages as Waialua Chocolate.



Note growth measures started at direct seed planting and seedling transplanting





Direct seeded roots (L) roots of transplants held in pots too long.
Producing transplants is costly and risky.



Open field evaluation of cage coverings for seed planted establishment

2011 June planted, compared films vs uncaged.

Uncaged died by 270 d, mats and films without UV inhibitors degraded by 370 d, best growth white latex on clear 6 mil UVR film > white 6 mil UVR film > clear 6 mil UVR film. Nursery trees were smaller and pot bound. Clear film was warmer and brighter than opaque.

2011 September planted, compared UVR films, clear, latex painted, white with similar results.

Both experiments were over head irrigated.



2013 February planted.

Compared these factors at different levels:

UVR covers June 2013 % of daily mean lux of unshaded sensor
% of daily mean temp of shielded sensor

1- clear, latex painted clear 6 mil film	24%	85%
2- white 6 mil film	26%	84%
3- 50% shade, black woven UVR cloth	33%	85%

Weed control system

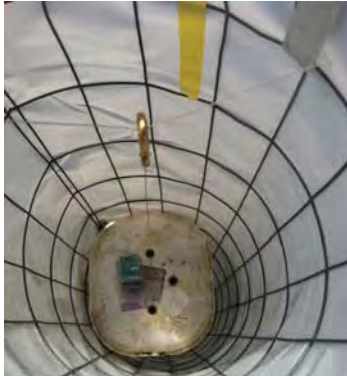
- 1- black UVR woven, weed mat installed Dec 2012
- 2- RoundUp® herbicide sprayed after mowing Dec 2012 and May 2013.

Cage height (2"x4" mesh galvanized fencing).

- 1- 3 ft
- 2- 4 ft

Drip irrigated, 10 g 15:15:15 2 month slow release at 4 months





Light and temperature measurement



Jeffrey Caraballo planting



Harvesting



2013 Oct Harvest 9 months after planting

	Basal dia. mm	Plant height cm	Plant dry wt. g
UVR covers			
1- latex	15.8	96	65
2- white	16.5*	87	57
3- black shade	14.8	93	52
Weed control			
1- Weed mat	16.2	104**	71**
2- Herbicide	15.2	80	45
Cage height			
1- 3 ft	16	97	67**
2- 4 ft	15.4	87	50



Best treatment Latex on clear film, on weed mat, 36" cage





Best management practices for direct seeding cacao.

Plant 2 seeds fresh from pod. Thin to 1 at 6-12".

If soil is not well prepared make small hole and fill with potting media / compost, cover < 1 " .

Have drip irrigation ready, weed control, and cage system – least expensive fencing 3-4 ft, covered, reusable stake and cable tie. Select cage covering suitable for site.





Cages cost \$5 each including labor, easily lasting 4 or more uses.

Use 6 mil UVR clear film for rainy or shaded areas, white film or 50% shade cloth for sunny areas, 36" tall by 10" dia.

4-5 ft wide woven weed mat reduces weed competition.

Trees can grown as seedlings or grafted in the cages.



Improving Establishment

Plant windbreaks before cacao.

Rapidly growing windbreaks are:

Bana grass reaches 20 ft in one year

Sudax 6-8 ft in 6 months.

Both are sterile and should be temporary. Plant sudax seed, plant bana grass stems.

Permanent wind breaks:

Banana 8 to 20 ft and panax 10-12 ft are fairly fast. Plant panax as rooted or unrooted stem pieces larger than 1.5 inch diameter, 3-4 ft long these can be in the orchard.

Orchard sides can be forest, mango, avocado, neem, areca palm, 'Be Still' etc.

Overhead shade and wind calming are Gliricidia (madre de cacao), sterile haole koa (KX4), papaya good for very dry, windy, and hot sites. Plant in cacao rows, space shade 20-30 ft apart.



Use cages to protect seedlings & young trees



2 fresh seed on side, covered 0.5 inch with moist potting soil, media or compost.



Seedlings at 4 weeks; keep one, cut or transplant other.

13 month seedling from 4 ft cage.

Protection from string trimmer, herbicide, weeds, wind, sun, beetles.



Fermentation

Harvests are smaller in Hawaii on new and small (< 1 acre) farms. 30 lb ferments are common. Plus our climate frequently means seeds set to ferment are 10-20F cooler than other cacao regions. Plus those areas have larger ferments, 300-1000 lb. Fermentation normally involves wild yeast, acetic and lactic acid forming bacteria. If the ferment has not reached 113F in 48 hr mold and other bacteria may ruin the ferment.



Fermenting HSCT samples

Experimental evaluation of new selections is done by putting the seed in net bags, placing the bags in the middle of a new ferment. The surrounding mass of seed supplies the heat and microorganisms to ferment the seed in bags. A drawback is the mass can alter the flavor of the selections and a large supply of pods must be available to supply the mass. We used this once to get a preliminary evaluation.



I did not have access to enough extra pods on a regular basis to use the batch method. A method to ferment seed from one to few pods at any time was needed. Knowing that ferments should start at 85F and reach > 120 F; an incubator was used to warm and then raise the temperature with various fermenting vessels.



Mold was frequent problem so we added consumer grade yeast to out compete the mold. This worked except chocolate tasted yeasty or alcoholic.



Clear plastic tubs with perforated lids for drainage worked slightly better. Loren Gautz developed a modular system based on acrylic tubes with a 'floating' lid to accommodate different volumes. We still had the occasional mold problem, seldom had any acetic acid (vinegar aroma) and the tubes leaked the sweet and sour liquefied mucilage.



Creating an inoculum

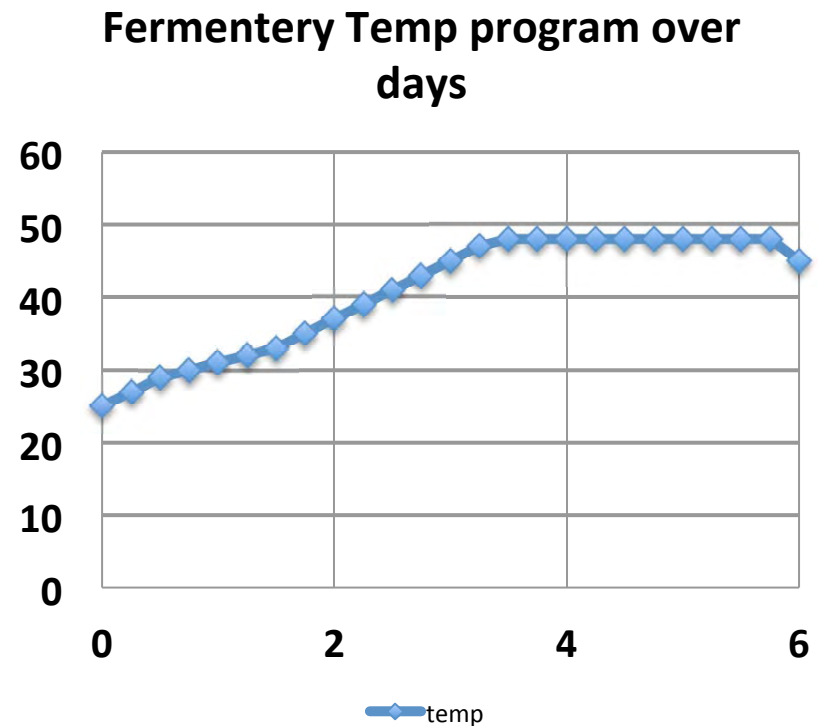
Vinegar flies (*Drosophila*) are found around fermenting cacao. We tried whole and crush flies to enable the ferment. Jeana Cadby reared flies. Ferments were good but somewhat laborious for our needs. Certainly a farmer should allow these flies in the fermentery area.



Current fermentation for HSCT



Gautz installed programmable temperature controller in an abandoned insect rearing unit. Fermentary warms to a set pattern.



Pods are opened, seeds removed, pods rolled in seeds to inoculate. Plastic bags are sealed with clothes pins to create anaerobic conditions favoring yeast to produce ethanol instead of CO₂. Bags unsealed and seeds mixed, bags cut to drain mucilage and to aerate at 48 and 96 hr, ending at 144 hr (6 d).





Sealed bags in pans.
Fermentery with ambient air bubbled through water.
Drying racks in lab stacked for ambient air drying with fan for 24 hr. followed by forced air at 95F and 122F each 24 hr, then 140F until 7 % seed moisture.



Improving Fermentation

Use a fermentery that is closed to breezes and held at 80-85F. This can be an insulated wooden, metal, or plastic shed.

Use wooden boxes (fermenters) that hold at least 30 lb fresh seed. Wood should not be pine or other resinous wood that might flavor cacao. Provide for drainage holes for mucilage but prevent drying and too much air by covering with banana leaves 2-3 layers and lid. Wood will inoculate next ferment.

Yeast forced to use up the air so that they are forced to shift from carbon dioxide production to alcohol production. Alcohol is used by acetic acid (vinegar) producing bacteria. The high temperatures and acetic acid kill the seed and improve the quality of the fermented cacao seed.

Each ferment can be different, monitor temperature in the ferment with a long stem digital or compost thermometer. Temperature should reach 122 F (50C). Rule of thumb turn or mix the ferment after 2 d and 4d.



Extension



Talking with farmers and would be farmers on Kauai and below at 3 annual Hawaii Chocolate and Cacao Association conference.

My annual Hawaii Cacao survey tracks industry growth.
I helped organize of the HCCA in 2011.



Harvesting

Green pods ripen to yellow. Red / purple pods ripen to orange.

Scratch surface of pod, if green under skin not ripe, if orange / yellow ripe.



Pods can be stored for 7 to 10d, depending how old they were at harvest. Store in large garbage bags or bins to prevent water and mucilage loss. **DO NOT STORE** below 60F as chilling injury can occur.

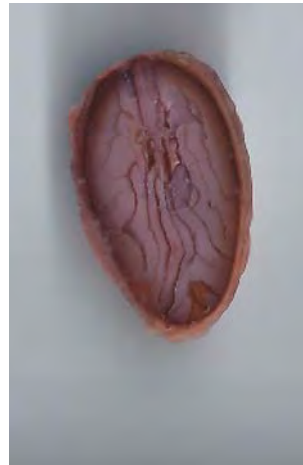


Cut seeds to follow ferment

Cut 10 random seeds lengthwise at 5 d to look at progress.



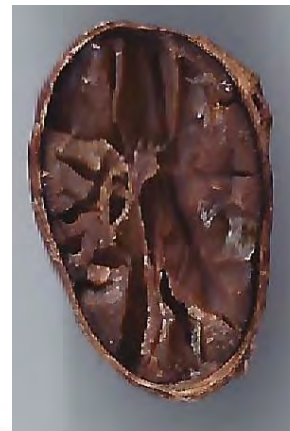
Fresh d 0
Dry d 0



Fresh d 5
Dry d 5



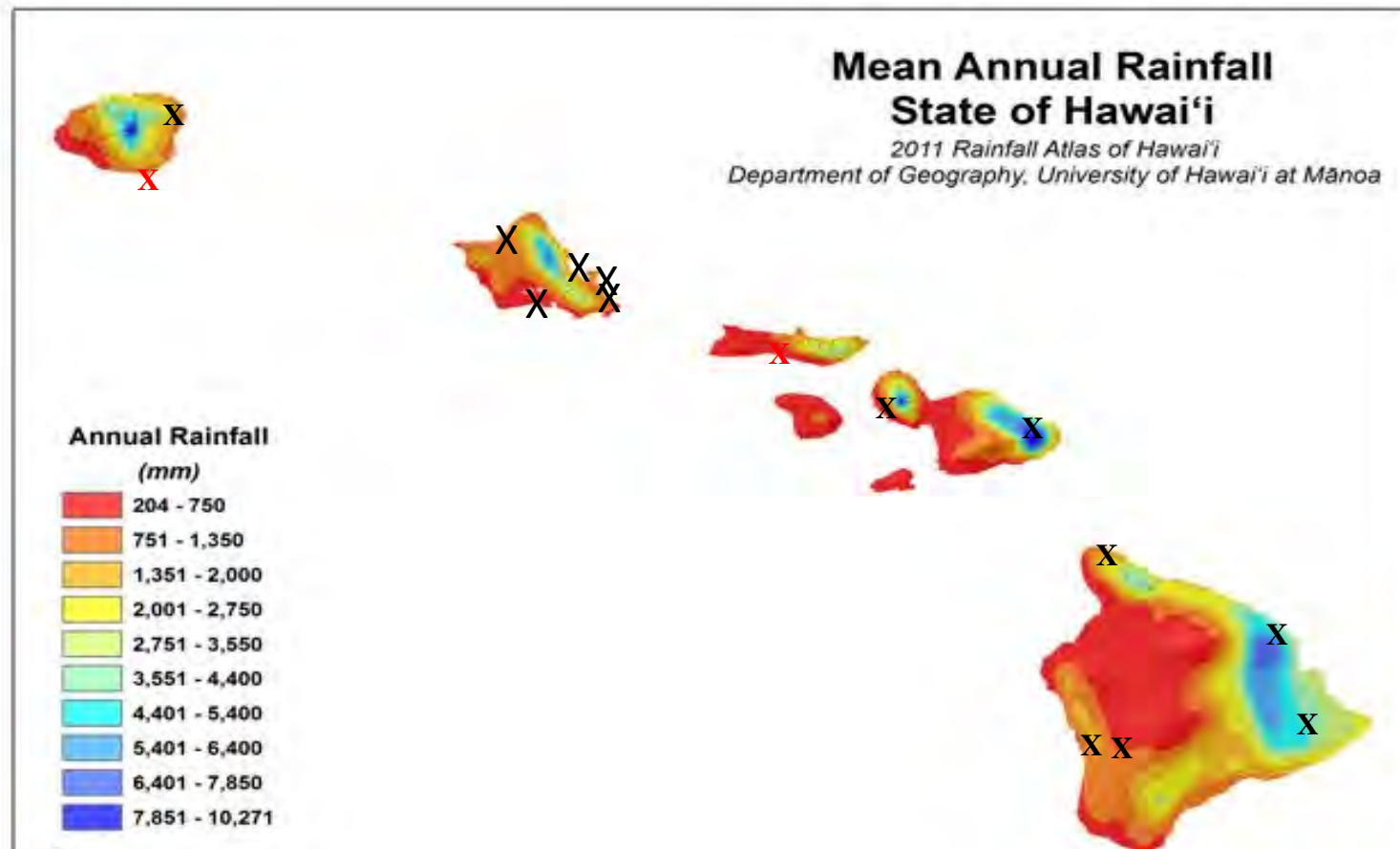
Fresh d 7
Dry d 7



When ending the ferment, aroma should vinegary to sour not rotten. Spread seeds to dry in sun 2 inch deep, turn several times the first day. This insures uniform drying. Dry to 6-7% moisture. Let the dry , fermented seeds "rest" in a dry, ventilated, insect-free area for 4 wk before roasting.



Hawaii State-wide Cacao Trial Sites



Kualoa Ranch

makai near fishpond windward Oahu

At planting



1 yr



3 yr

Best yielders (dry seed lb/acre) to date in the second year of harvest (4 yr old trees) are selections:

1- 960

3- 1300

ICS 95- 570

Amelonado- 380

Site average- 670



CTAHR / UH Urban Garden Center lower Pearl City, Oahu

1 yr



Best yielders (dry
seed lb/acre) to date
in the second year of
harvest (4 yr old
trees) are selections:

4- 910

6- 880

ICS 95- 340

Amelonado- 700

Site average- 620



3.25 yr



Current Status of Cooperator Sites

To date we planted 13 sites (520 grafted) on Hawaii, Maui, Oahu, and Kauai. Unfortunately 6 have been abandoned by cooperators or destroyed by mishaps. Lack of funding made it impossible for regular visits to neighbor island sites.

We developed a technique to transport bare rooting, grafted plants, for carry on that can be held 2 days in darkness with good excellent survival.

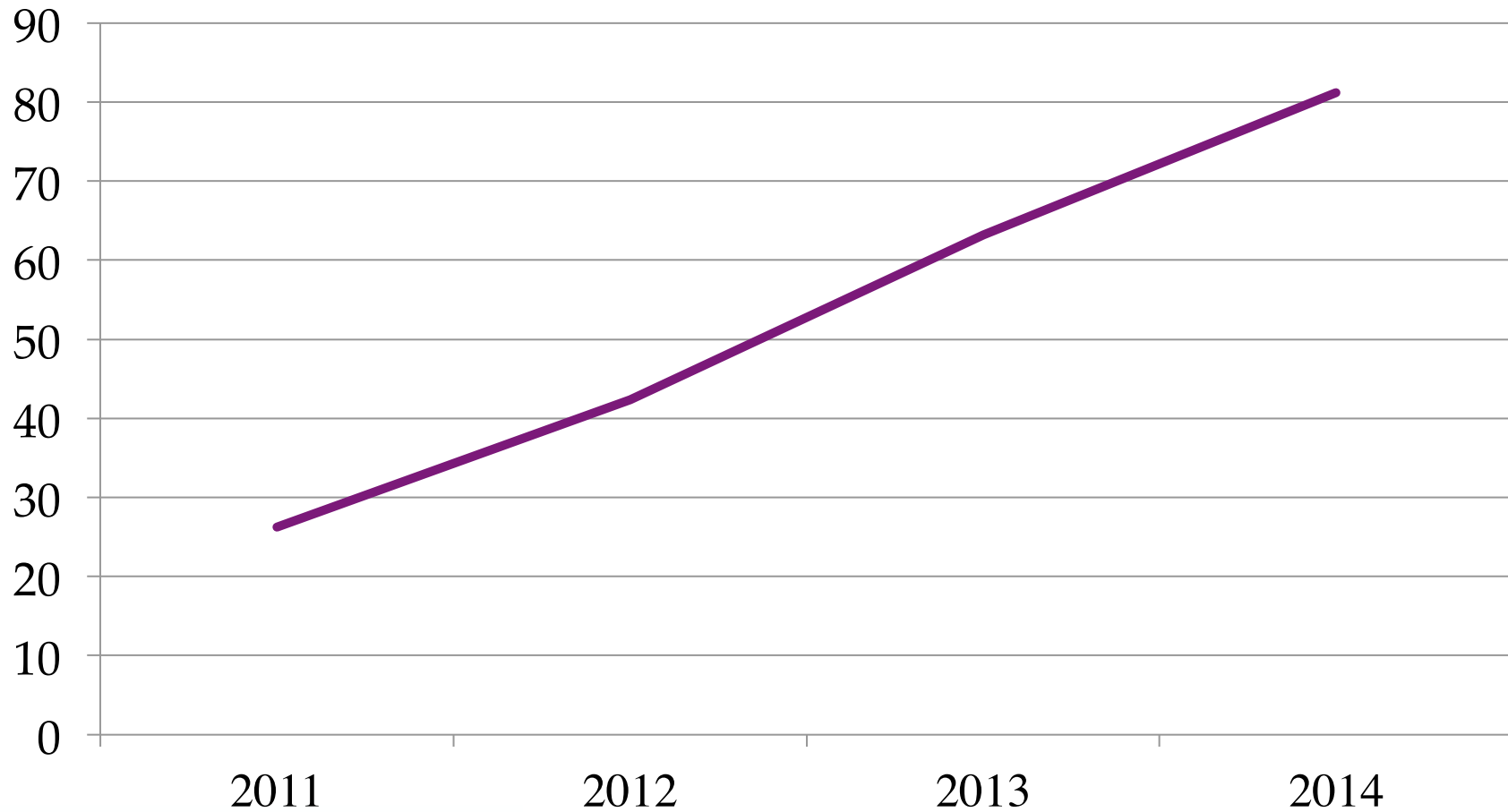
Three Oahu sites-Kualoa, Pearl City and Waimanalo are doing well, yield data collected, fermented and dry seeds sent for evaluation.

Any new sites will be grafted in cooperator nursery or in their orchard.



Is Cacao expanding ?

Acres Planted



Questions ?

