GOFARM HAWAI'I
UNIVERSITY OF HAWAI'I

Upland Taro Cultivation Manual

A HOW-TO GUIDE ON CULTIVATION BASICS & BUSINESS BEST PRACTICES

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By following the guidelines in this manual, you will be equipped to cultivate taro successfully, whether you are an experienced farmer or new to taro cultivation. The goal is to support you in achieving high yields of top-quality taro, contributing to the sustainability and profitability of your farming operations. This manual, with its detailed economic analyses, aims to provide you with a comprehensive understanding of the financial aspects of taro production, guiding strategic decisions to enhance farm viability and profitability.

Culture & Community

Culture & Community
While information shared in this manual on the cultivation of taro is primarily focused on practical guidance, it is essential to recognize the extensive historical and cultural context of Native Hawaiian use and relationship with this plant, and the land and people connected to it.

The following components are important to be aware of when practicing agriculture and planting taro (kalo) in Hawai'i.

Indigenous Wisdom & Scientific Knowledge
With taro cultivation, oral tradition and indigenous knowledge are particularly strong, and provide lived experience and practices that shape how taro is grown today. Scientific approaches to develop and evaluate varieties and increase quality and yield also support the ongoing cultivation of taro. These different ways of knowing are equally important for the success of regenerative agriculture when looked at through a native and indigenous lens. We seek to share the value of both perspectives and points of reference.

Hawaiian Identity
'Ōlelo Hawai'i (Language): Kalo is the Hawaiian word for taro and is often interchangeable in conversations in Hawai'i when referring to taro.

Kalo (Ancestors): Not only a crop for production, Kalo is revered as an ancestor for the Hawaiian People, and referred to as Hāloa in the Hawaiian Creation Story, the Kumulipo.

> **The Story of Hāloa:**
> Hāloa was the first human born to the gods, conceived by Wākea, the sky father, and Ho'ohōkūkalani, their daughter. However, Hāloa was stillborn and buried in the ground, wrapped in hala. From the place of his burial, a plant grew, which became the first kalo plant. The story also says that Ho'ohōkūkalani later gave birth to another son, also named Hāloa, who became the first Hawaiian.

'Āina (Land):
The literal translation of 'āina is "land," but as a cultural concept it reflects a connection and reciprocal relationship with the land and its resources. The concept of 'āina goes beyond land as an asset for utilization, but rather as an entity that produces crops and sustains the overall health of the community.

Culture & Community

Inoa (Names): Elemental variations often have specific names, usually closely associated with their attributes and sometimes a particular place. For example blustering winds and breezy winds would have different names, as would a light rain and a heavy rain. The inoa for winds and rains provide insights on weather patterns and climate considerations that Hawaiians considered invaluable in their farming practices and protocols. Many reference translations have been lost as common knowledge but can still be identified through traditional academic research as well as shared storytelling from stewards, residents, and community leaders.

Waiwai (Abundance): Translates as Wealth. The word Wai on its own means water and as a literal pairing Waiwai translates to lots of water. As a cultural concept, water is the source of life, therefore if you have lots of water you are considered wealthy. Viability and vitality are inherently connected to water access and care for ʻāina, which lead to sustenance and quality of life.

Protocol

If you are unfamiliar with a location being cared for by someone else, ask permission to enter. Identify who to contact and respect the privacy and place of others regardless of whether or not your access is granted. This step is often overlooked by western/non-Hawaiian cultures and has created contention amongst different cultural communities.

If you are invited and accepted to enter and participate, traditional protocols vary based on place and practitioner. Often it is appropriate to bring an offering in the form of wai (water), oli (chant), leo (words), or mele (song) from your place to share with the ʻāina you visit. ʻĀina is considered sacred to the Hawaiian people, when entering a cultural space it is best to check in with the steward or practitioner of the location before you arrive to ask what would be appropriate.

Generations of Knowledge

As we continue to build curriculum with a cultural lens it is important to recognize that knowledge (ʻike) does not only come from academic research, and that valuable and practical information continues to be passed down from generation to generation within the community. In linking academia and culture we hope to create a more comprehensive educational pathway that is inclusive of academic, cultural, and practical perspective.

Hawaiʻi has many cultural influences that are incorporated into farming and we wish to recognize and acknowledge the importance of historical cultural and agricultural practices and the relevance of these today, alongside other types of scientific and technical research.

We welcome inputs from the community to continue to improve accuracy and respect for ʻāina and the communities that serve it. If there are resources that you would like to share, please contact us at info@gofarmhawaii.org.

Introduction

Taro, a crop with significant culinary and cultural value in Hawai'i, requires specific growing conditions and care. This manual is a resource for farmers and agricultural enthusiasts who are interested in taro cultivation. It covers essential aspects of taro farming, providing detailed instructions using sustainable practices. This manual aims to help you achieve optimal yields and high-quality production with step-by-step guidance on each critical component of taro cultivation.

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Category 1: Field Preparation

Introduction

Field preparation is crucial for the optimal growth and yield of upland taro. This stage involves preparing the soil to create the best possible environment for taro roots to develop, ensuring they have access to necessary nutrients and proper drainage.

Objectives

- To clear the land of any residues, weeds, or debris that could harbor pests or compete with taro for nutrients.
- To improve soil structure and fertility to support healthy taro growth.

Materials and Tools Needed

- BCS-type tractor with rotary hoe and rotary plow for small-scale farming
- 4-wheel tractor with disk harrows and plows for larger-scale operations
- Equipment for deep ripping (optional)
- Soil testing (see Category 2)

BCS Equipped with Power Harrow
(Photo: GoFarm Hawai'i)

Step-by-Step Instructions

- **Step 1**: If land is covered in heavy biomass from cover crops or weeds consider mowing down the biomass first to make clearing easier. Clear the land of weeds, debris, and any residual crops using appropriate tools based on the scale of your operation (rotary hoe for small-scale, tractor with disk harrows for larger scale).
- **Step 2:** Conduct a soil test to assess nutrient levels and pH. Collect soil samples properly to ensure accurate results. **See Category 2 for more instructions.**
- **Step 3:** As needed, do additional plowing using a rotary hoe or power harrow for small-scale operations or a tractor equipped with disk harrows for larger areas. The goal should be to minimize large clods and loosen the soil to enhance aeration and drainage.
- **Step 4:** OPTIONAL Consider deep ripping every 3-5 years, especially if your soil is prone to compaction. This process breaks up deeper soil layers, improving water infiltration and root penetration.

Results

- Well-prepared soil that is loose, well-aerated, and rich in nutrients, ready for the successful cultivation of upland taro.

Category 2: Taking a Soil Sample

Introduction
Having accurate soil data can greatly benefit yields and save money. Proper soil sampling is essential for reliable soil test results.

Materials Needed
- Clean, non-rusty shovel
- Clean plastic bags for soil collection
- Clean bucket for mixing sample
- Permanent marker for labeling samples

Confirming Proper Sample Depth
(Photo: GoFarm Hawai'i)

Step-by-Step Instructions

1. **Prepare Equipment**
   - Ensure your shovel is clean and rust-free. Clean it as needed between samples to avoid cross-contaminating the soil samples.
2. **Select Sampling Locations**
   - Segment your growing area into logical areas based on visible differences in soil color, texture, or past crop performance. Even on a small farm, these variations can significantly impact soil nutrient levels.
   - At each location, plan to collect a soil sample that is representative of that area.
3. **Sampling Depth and Method**
   - Begin by removing the top 1-2 inches of surface soil from the sampling area, as this layer often contains debris and is not representative of the soil where taro roots grow.
   - Aim to sample to a depth of 8 inches, which is the active root zone for most taro plants.
4. **Collect and Handle Soil Samples**
   - Using the shovel, dig a small hole to your predetermined depth.
   - From the side of this hole, slice a vertical section of soil trying to capturing the soil profile from top to bottom.
   - Collect at least 5 such slices from various points across each defined area of your farm, mixing them together in a clean bucket to create a composite sample for that section.
   - Collect approximately 2 cups of the composite sample and put it in a clean plastic bag.

Category 2: Taking a Soil Sample

Tips and Best Practices

- Avoid sampling immediately after fertilization or heavy rain, as these conditions can skew results.
- Stay away from unusual spots like old fence lines, roadsides, or any areas where debris accumulates.
- Label each sample bag with the date and specific location details using a permanent marker. This practice is crucial for tracking soil fertility changes over time and managing nutrient application effectively.
- Store samples opened and in a cool dark place for no more than 48 hours before shipping.

Further Actions

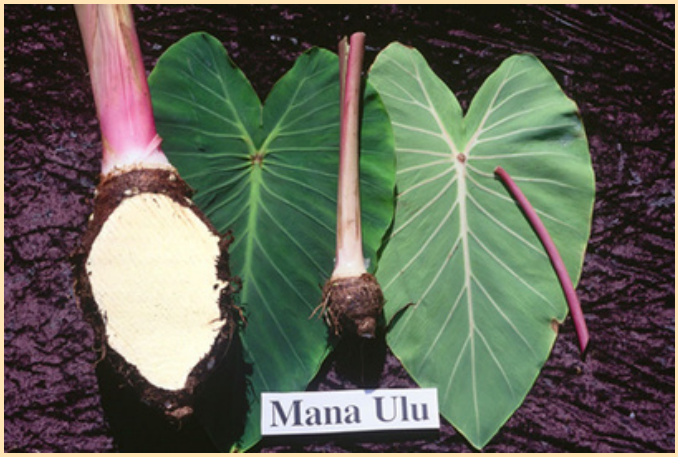
- Send your composite soil samples to a trusted agricultural lab for analysis. Be sure to inform the lab of your crop plans and sampling method, and discuss any specific crop concerns you might have.
- GoFarm Hawai'i uses and recommends Crop Nutrient Solutions, Inc. a Hawai'i-based independent consultant specializing in soil and plant nutrition. Contact them prior to sending a sample.

Taking a vertical sample of the soil to capture soil profile from top to bottom
(Photo: GoFarm Hawai'i)

Category 3: Variety Selection

Introduction

Selecting the right variety is a key part of achieving a successful crop. Varieties greatly differ not only in their suitability for producing luau leaves or corms but also in their adaptability to upland environments. It is crucial to recognize that there are many varieties (many not listed in this manual) that may thrive in your specific area. Experimentation and testing are key to understanding what works best. Finally, the intended end use of the taro is a critical factor in variety selection. For instance, if producing poi is your goal, choosing a variety specifically suited for poi production is essential.



Photos: University of Hawai'i College of Tropical Agriculture and Human Resources

Variety Categories

- **Hawaiian Varieties:** These are traditional cultivars long cultivated in Hawai'i, revered for their cultural significance and adapted to local conditions.
  - **Mana** group varieties are known to do well in upland environments. They are excellent as table taro but usually don't make good poi.
  - **Ele'ele** group are often grown in upland conditions. They are known as the "royal black taros" and make red poi of excellent quality.
  - **Lehua** group can be grown in dryland conditions and are known to make poi of excellent quality.
  - **Moi** is mainly grown in lo'i conditions but can also thrive in upland areas. Good for poi.
  - **Piko** varieties can also do well in upland conditions, and make excellent poi.

Category 3: Variety Selection

- **Hybrid Varieties :** Developed to enhance disease resistance and increase yield, hybrids like Pa‘lehua, Pa‘akala, and Pauakea offer advantages such as shorter maturity times and resistance to taro leaf blight. Pa‘lehua is good for both leaf and corm production under upland conditions, and is heavy-yielding with 6 to 8 lb corms.
- **Imported Varieties:** Includes varieties like ‘Bun Long’, known as "Chinese taro," which is preferred for its large, tender leaves making it ideal for luau production. Japanese cultivars are more similar to dasheen varieties, while being hardier, with higher yields and better disease resistance.

Photos: University of Hawai‘i College of Tropical Agriculture and Human Resources

Recommendations for Luau Leaf Production
For dryland luau leaf production, Bun Long is excellent for its prolific leaf production but can be too mushy for laulau. Hybrid varieties like Pa‘lehua have vigorous leaf growth and blight resistance, making them suitable for areas with disease pressure.

Recommendations for Corm Production
For corm production, the focus is on varieties that yield large, flavorful corms. Lehua Maoli is traditionally favored for its high-quality corms ideal for poi. Among hybrids, Pa‘akala and Pauakea are recommended for their large corm sizes and good storage qualities, however, they will not make satisfactory poi.

Category 4: Planting

Introduction
Planting is one of the most critical aspects in cultivation. Starting with poor planting material or poor planting methods will directly affect yield and quality at harvest.

High Density Nursery Planting
(Photo: GoFarm Hawai'i)

Staggered Double Row for Leaf Production
(Photo: GoFarm Hawai'i)

Huli Preparation and Sanitation

- **Prepping the Huli:** Start by selecting healthy mother plants free of pest and disease. This is very important. Harvest the huli to include a portion of the corm and a section of the stem. Size of huli can vary greatly in length and should always have around 0.25 to 0.5 inch of corm still attached.

- **Cleaning and Sanitizing:** Cleaning and sanitizing the huli can dramatically reduce disease introduction into your field. This is especially important when bringing in new huli from other locations. Clean the huli by soaking in a soapy water solution for 30 seconds to 1 minute, then rinse thoroughly. Sanitize using a 10% chlorine solution (1 part bleach to 9 parts water) for 10 minutes or a peroxyacetic acid solution (25 fluid ounces per 50 gallons of water) for at least 45 seconds. Allow the huli to dry in a shaded area before planting.

- **Huli Storage**: Huli should be planted as soon as possible. It is possible to store huli for up to 1 week but quality may diminish. Ideally store in a shaded, dry place. Spread huli out and don't store it in large piles.

Category 4: Planting

Sorting and Planting Huli

- **Sorting Huli:** Before planting, sort huli by size, based on the bottom diameter. This is important for promoting uniform growth rates and corm sizes, leading to more consistent maturity across the field. Plant different sizes in different rows or areas.

- **Planting Depth and Orientation:** Plant huli at least 4 inches deep to ensure stability and encourage root development. Ensure the huli are planted upright with the cut end down and the leaf stalk end pointing upwards. Consider row orientation parallel to prevailing wind direction to decrease pest issues.

Wider Spacing Single Row for Corm Production
(Photo: GoFarm Hawai'i)

- **Spacing Recommendations:**
  - **Experiment** with spacing at your site to see what works best. Tighter spacing can increase insect and disease pressure. Wider spacing will result in larger plants and bigger corms.
  - **Nursery Production:** For instances when you are growing to multiply planting material, use closer spacing of about 0.75 to 1 foot staggered double rows on a single bed. Space 3 feet between beds for efficient space use and management.
  - **Leaf Production (Lau):** Space huli 1 foot apart in a staggered double row per bed with 3-4 feet between beds to maximize leaf yield.
  - **Corm Production (Kalo):** For corm growth, space huli 2 feet apart in a single row per bed with 5 feet between rows to allow sufficient space for corm development and to reduce nutrient competition. Test wider spacing (3 feet) for heavy-yielding hybrid varieties.

Category 5: Irrigation

Introduction

Irrigation plays a pivotal role in the successful cultivation of upland taro, significantly impacting plant growth and yield. Ideally taro should receive ample water and never be allowed to dry out during the grow out for maximum production. This category provides a guide for setting up and managing an irrigation system for taro cultivation.

Irrigation Needs and Practices

- **Understanding Water Requirements:** Upland taro thrives under moist but well-drained conditions. Consistently maintaining moist soil and not allowing the field to dry out will maximize growth rates, quality and yields. However, upland taro does not like ponding or standing water.
- It is important to know your cost of water and estimated water usage. If water is limited or expensive consider practices that can improve moisture retention like mulching.
- Designing irrigation systems to match your water availability may require an engineered design to work best. This manual makes recommendations, but each site and system are different and may need tailored solutions.

Riser Valve Connect to Sub-main
(Photo: GoFarm Hawai'i)

System Setup and Management

- **Materials and Tools Needed**
  - Drip irrigation tubing with emitters
  - Oval hose (1 inch minimum)
  - Locking connectors
  - Riser valve with screen filter and pressure regulator
  - Timer or irrigation controller

Category 5: Irrigation

Step-by-Step Instructions

1. Designing the System:

- **Plan the Layout:** Measure the area to determine the length of oval hose and the amount of drip tubing required.

2. Installation of Riser Valve and Sub-main Lines:

- **Installing a riser valve including screen filter and pressure regulator:** Install a riser valve at your main water supply near the growing area.

- **Laying sub-main:** Using oval hose connect to riser valve and run oval hose perpendicular across all rows. For small plantings (<2000 sq. ft.) use 1-inch oval hose. For larger plantings use 1.5-inch oval hose.

Drip Tube Connect to Sub-main
(Photo: GoFarm Hawai'i)

3. Drip Line Setup:

- **Laying Drip Tubing:** Roll out drip tubing along each taro row, securing it at intervals with soil staples to keep it in place. Hose should be installed on top of rows with emitters facing up. Connect tubing to oval hose using locking connectors. If water pressures allow, consider installing two lines of drip tape, one on each side of the taro. This can improve wetting distribution and allow for more water to be applied in a shorter time period.
- **Type of tubing:** Except for in special circumstances, typical drip irrigation hose of 8-10mm thickness with emitter spacing anywhere from 8 to 12 inches will be fine.

4. System Testing and Adjustment:

- **Test the System:** Run water through the system to check for leaks and ensure all parts are functioning correctly.

5. Install programmable timers (optional):

- **Programming:** Connect the timer or controller to automate irrigation based on schedule, ensuring soil maintains consistent moisture.

Category 5: Irrigation

Monitoring and Adjusting Irrigation: Continual monitoring of soil moisture and plant conditions is critical to a successful crop.

- **Recommendation:** Using typical drip irrigation hose, start with 1 hour per day of irrigation and adjust accordingly. You want to ensure the soil in the root zone does not dry out.
- During peak growth periods or dryer seasons, increase irrigation frequency to maintain optimal soil moisture. Two irrigation rounds per day may be required.
- Some farms reduce watering as plants near maturity to encourage corm hardening and to make it easier to harvest.

Tips and Best Practices

- Regularly inspect the system for leaks or clogs and clean filters as needed.
- Consider the local climate and weather patterns when setting irrigation schedules to avoid over-watering or under-watering.
- Mulching wood chips or installing plastic mulch around plants will reduce evaporation and maintain soil moisture.

Wood Chip Mulching Under Taro to Improve Moisture Retention
(Photo: GoFarm Hawai'i)

Category 6: Crop Nutrition-Cover Crops

Introduction

Cover crops are a vital component of sustainable agriculture, providing numerous benefits such as weed control, erosion prevention, soil fertility enhancement through nitrogen fixation, organic matter addition, and pest suppression, including nematodes.

Reasons to Cover Crop

- To enhance soil structure and fertility, and increase organic matter content.
- To control soil-borne pests, particularly nematodes, using non-chemical methods.
- To suppress weed growth and reduce soil erosion.

Sunn Hemp Cover Crop
(Photo: GoFarm Hawai'i)

Materials and Tools Needed

- Seeds for selected cover crops
- Basic sowing equipment (seed drill or broadcast spreader)
- Soil preparation tools

Step-by-Step Instructions

1. **Selection of Cover Crops:**
    - Choose cover crops based on their benefits and soil/environmental conditions:
        - **Marigold:** Effective in reducing nematode populations due to its nematicidal properties.
        - **Sunn hemp:** Known for rapid biomass production and nitrogen fixation.
        - **Sorghum-sudangrass hybrids:** Enhance soil structure and with some suppression of nematodes.
    - **Cover Crop Mixes:** Use multi-species mixtures to maximize benefits. For example, combining a rapid-establishing crop like buckwheat with a high biomass producer such as sorghum-sudangrass can enhance weed suppression and improve soil health simultaneously. These mixes can include multiple different plant species, each selected for specific traits such as biomass production, nitrogen fixation, and pest suppression.

Category 6: Crop Nutrition: Cover Crops

2. **Timing and Planting:**
    - Plant cover crops at the end of the taro crop or during a fallow period. Ideally, they can be timed with onset of rain events to limit the amount of irrigation water required.
    - Prepare the soil by light tilling, and sow the seeds at the recommended depth and rate for each species. If using a mix of seeds, balance the seeding rates to ensure all species can establish.
3. **Termination:**
    - **Optimal Termination:** Determine the best time to terminate the cover crops based on their life cycle and the needs of the upcoming taro crop. Typically, cover crops should be terminated before getting woody or setting seed to ensure their nutrient composition is high. Terminate cover crops by mowing or lightly tilling the crops into the soil.
4. **Incorporation into Soil:**
    - Depending on your strategy, you can either leave the cover crops on the surface as mulch or till them into the soil. If opting to till the cover crops into the soil, do so at least a few weeks before planting taro to allow sufficient time for the organic matter to decompose, which will release nutrients back into the soil and improve its structure.

Sunn Hemp Cover Crop After Incorporation
(Photo: GoFarm Hawai'i)

Tips and Best Practices

- Mixing different types of cover crops can provide broader benefits. For instance, combining a legume with a grass or cereal can improve soil structure while fixing nitrogen.
- Ensure that the chosen cover crops do not host similar pests or diseases as taro to avoid any negative impacts.
- Repeated plantings of cover crops can significantly reduce the need for fertilizers and pesticides by improving soil health and reducing pest populations naturally.

Category 7: Crop Nutrition - Soil Amendments

Introduction

Adding soil amendments before planting taro is crucial for optimizing soil health, enhancing nutrient availability, and ensuring strong plant growth. This is particularly important for organic growers with inputs that require longer mineralization rates.

Objectives

- To enhance soil fertility and structure prior to planting taro.
- To adjust soil pH and replenish essential nutrients using appropriate amendments.
- To ensure even distribution and effective integration of amendments into the soil.

Materials and Tools Needed

- Soil amendments: compost, and meat and bone meal (MBM)
- Calcium: from ground coral, lime or gypsum. Coral and lime will also raise your soil pH
- Soil test results (See Category2)
- Spreader for even distribution of amendments
- Tillage equipment for incorporating amendments

Meat and Bone Meal Amendment
(Photo: CTAHR)

Recommended Soil Amendments and Application Rates

The application rates provided are adjusted for a 100-foot row (approximately 400 square feet of cultivation area).

Step-by-Step Instructions

1. **Soil Testing:**
   - Conduct a soil test following instructions in Category 2, to determine the current pH level and nutrient content, particularly focusing on nitrogen, phosphorus, potassium, and calcium levels.
2. **Amendment Selection and Preparation:**
   - Based on the soil test results, select the appropriate amendments to balance soil nutrients and pH.
   - Without a soil test, general recommendations for each amendment are provided in the table below.
   - For all amendments, apply and incorporate approximately two weeks prior to planting.

Category 7: Crop Nutrition: Soil Amendments

3. **Application of Amendments:**
    - Spread the amendments evenly across the designated area using a manual or mechanical spreader.
    - Distribute the specified amount as evenly as possible across the bed.
    - For organic systems add MBM (also known as tankage), and spread as evenly as possible across the bed. Conventional growers using synthetic fertilizer can skip this step.
4. **Incorporation into Soil:**
    - Use tillage equipment to mix the amendments into the top 6-12 inches of soil (see Category 1). This helps to integrate the amendments thoroughly and makes nutrients more accessible to the taro plants.

Amendment	General Application Rate Without Soil Testing	Purpose
Gypsum or lime	15 lbs per 100 ft. Row	Improves soil structure, adds calcium and reduces aluminum toxicity in acidic soils. Note: lime will raise soil pH.
Compost	Up to 100 lbs per 100 ft. row	Improves soil structure, moisture retention, microbial activity, and disease suppression
Meat and Bone Meal (MBM)	15 lbs per 100 ft. row	Provides a slow-release source of nitrogen and other nutrients

Tips and Best Practices

- Ensure that amendments, especially organic ones like compost, are well-decomposed to avoid nitrogen drawdown which can affect young plants.

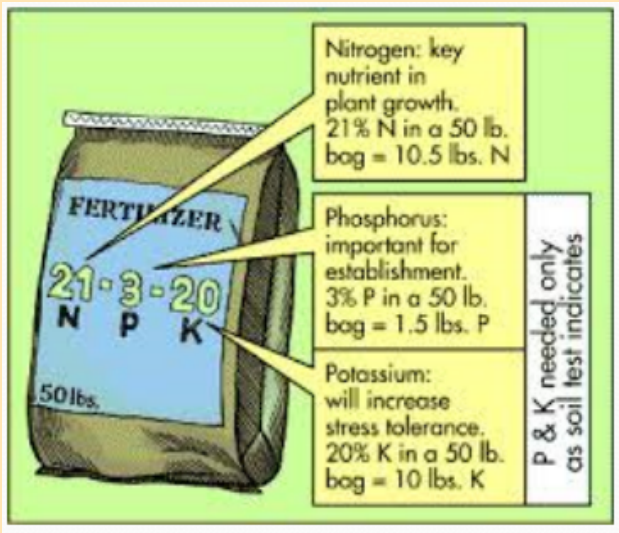
Category 8: Crop Nutrition - General Fertilization

Introduction

Proper fertilization is essential for achieving optimal growth and high yields in upland taro cultivation.

Objectives

- To ensure taro plants receive the right nutrients in appropriate amounts throughout their growth.
- To facilitate the efficient use of fertilizers, enhancing productivity while minimizing costs and environmental impacts.
- To offer both conventional and organic fertilization strategies to meet diverse grower needs.



N-P-K breakdown
(Image: CTAHR Fertilization PPT)

Materials and Tools Needed

- Conventional fertilizers (soluble N-P-K formulations)
- Organic fertilizers (meat and bone meal (MBM) and sulfate of potash)
- Fertilizer spreader for dry applications
- Injection system for soluble fertilizers
- Personal protective equipment for handling fertilizers

Fertilizer Selection and Application Rates

- The following table provides general application rates for both conventional and organic fertilizers. Rates should ideally be based on soil analysis results, but general recommendations are provided for situations where soil analysis is not available. These rates assume soil amendments are being done prior to planting as described in Category 7. Cover cropping and compost additions can help lower the rates of fertilizer application rates over time.

Category 8: Crop Nutrition - General Fertilization

Fertilizer Type	Fertilizer Type	General Application Rate	Specific Instructions	Timing of Application
Organic	MBM	15 lbs per 100 ft row	Broadcast evenly around plants and bed	Apply at 3 and 6 months after planting
Organic	Sulfate of Potash (0-0-50)	2.5 lbs per 100 ft row	Broadcast or solutionize and inject via irrigation	Apply at 3 and 6 months after planting
Conventional	15-5-15 Cal-Mag	5 lbs per 100 ft row	Solutionize and inject through irrigation lines	Apply at 2, 4, 6, 8 and 10 months after planting

Step-by-Step Instructions for Organic Fertilization

1. **Preparing Meat and Bone Meal (MBM):**
   - Measure the required amount of MBM based on the application rate provided.
   - MBM is difficult to inject through drip lines as it is prone to plugging up emitters.
2. **Application of MBM:**
   - Evenly distribute the MBM around taro and along the rows. Ensure that the MBM is spread near the base of the plants but not in direct contact with plant stems to prevent burning.
   - If possible, lightly incorporate the MBM into the topsoil using a rake or a hoe. This helps to place the nutrients closer to the root zone and prevents them from being washed away by rain or irrigation.
3. **Application of Sulfate of Potash:**
   - Sulfate of potash can be broadcasted with MBM or it can be solutionized and injected into the irrigation system.

Category 8: Crop Nutrition - General Fertilization

Step-by-Step Instructions for Conventional Fertilization

1. **Solutionizing Fertilizers:**
    - Dissolve the recommended amount of soluble N-P-K fertilizer in 50 gallons of water.
    - Utilize an injection system connected to your irrigation setup to deliver the fertilizer solution directly to the plant roots through the irrigation lines.
2. **Application Through Irrigation:**
    - Set up your irrigation system to run at a rate that ensures complete coverage of the root zone.
    - Inject the fertilizer solution at the start of the irrigation cycle to mix thoroughly with the water and reach all parts of the root zone. Attempt to make the injection in a slow manner (15+ minutes) to ensure adequate distribution.
    - Allow water to run for 1 hour after application.

Tips and Best Practices

- **Soil Testing:** Always base fertilizer applications on soil test results to ensure that nutrients are added according to the specific needs of the soil and crops.
- **Application Rates:** If soil testing is not conducted, use the general application rates provided but be aware of the potential risks, such as imbalanced soil nutrient levels, which can lead to poor crop health and reduced yields.
- **Protective Equipment:** When handling and applying fertilizers, especially when mixing and injecting solutions, use appropriate protective equipment to avoid exposure to harmful chemicals.

Troubleshooting

- **Deficiency Symptoms:** If plants show signs of nutrient deficiency, reevaluate your fertilization strategy and consider tissue testing to pinpoint deficiencies.

Category 9: Pest Management

Introduction

Effective pest management is crucial for maintaining healthy taro crops. Generally, pest pressure is less in upland cultivation as compared to wetland. This manual focuses on three common pests in upland taro cultivation: root-knot nematodes, aphids, and leafhopper. It provides integrated pest management strategies, cultural practices, and chemical control options, and highlights the importance of using resistant varieties and considering environmental impacts.

Objectives

- To manage and control nematode and aphid populations effectively in taro fields.
- To implement sustainable practices that minimize pest impact and promote healthy crop growth.

Common Pests in Taro Cultivation

1. **Root-Knot Nematodes (*Meloidogyne spp*.)**
   - **Identification:** Small, microscopic worms that cause galls or swellings on roots, leading to reduced nutrient uptake and weakened plants.
   - **Damage:** Infested plants show stunted growth, yellowing of leaves, and reduced yield.
2. **Aphids**
   - **Identification:** Small, soft-bodied insects that cluster on the undersides of leaves and stems, sucking sap and weakening plants.
   - **Damage:** Besides direct damage, aphids can transmit viruses like Dasheen Mosaic Virus, further impacting crop health.
3. **Leafhoppers (*Tarophagus proserpina*)**
   - **Identification:** Small insects that suck sap from the petioles and leaf blades, leaving behind characteristic brown to black spots from sap stains.
   - **Damage:** Heavy infestations can lead to significant sap loss, weakening the plant and reducing overall vigor.

Aphids Being Tended by Ants
(Photo: Scot C Nelson)

Category 9: Pest Management

Integrated Pest Management (IPM) Approaches

- **Monitoring:** Regular scouting of taro fields to identify early signs of infestation.
- **Signs of infestation:** Inspect leaves for presence of aphids. Leafhopper damage can be distinguished by the presence of numerous brown to black spots on the petioles.
- **Thresholds**: Establish action thresholds to determine when pest populations warrant intervention to prevent economic damage.
- **Ants:** Controlling ants in the field can help control aphids. Ants can spread and move aphids quickly around the field.

Signs of Leafhopper Damage
(Photo: Scot C. Nelson)

Cultural Practices

- **Clean planting material:** Do not plant huli infested with insects or from fields with heavy insect or nematode pressure.
- **Crop Rotation:** Rotate taro with non-host crops to disrupt the life cycles of nematodes and reduce insect populations. See Category 6: Cover Cropping for more information.
- **Fertility:** Maintain good nutrition to promote healthy plants.

Chemical Control

- **Nematicides:** Apply nematicides only at last resort. Apply only chemicals specifically labeled for use in taro to control nematode populations. Follow label instructions for application rates and timings.
- **Insecticides:** Use insecticides approved for use on taro to control severe insect infestations. Pyrethrins (Sample brand: Pyganic) and neem seed oils (Sample Brand: Trilogy) are both labeled for taro and can control insect pests.

Poor Growth from Nematodes
(Photo: Scot C. Nelson)

Category 10: Disease Management

Introduction
Effective disease management is crucial for maintaining the health and productivity of upland taro crops.

Objectives
- To identify and manage key diseases in upland taro cultivation.
- To implement integrated disease management (IDM) practices that enhance crop resilience.
- To minimize crop loss due to diseases through best practices.

Common Diseases in Upland Taro Cultivation

1. **Taro Leaf Blight (*Phytophthora colocasiae*)**
   - **Symptoms:** Water-soaked lesions on leaves that turn into black or brown spots.
   - **Management:** Use resistant varieties, ensure good field sanitation and avoid overhead irrigation.
2. **Corm Rot (*Pythium spp.*)**
   - **Symptoms:** Soft, mushy mass in corms; root decay
   - **Management:** Improve soil drainage and aeration, use clean and sanitized planting material and practice crop rotation.
3. **Dasheen Mosaic Virus**
   - **Symptoms:** Mottling and distortion of leaves.
   - **Management:** Control aphid populations to prevent virus transmission and remove infected plants promptly.
4. **Leaf Spot (*Phyllosticta colocasiophila*)**
   - **Symptoms:** Yellow brown to reddish brown spots on leaves.
   - **Management:** Remove infected debris, maintain adequate spacing and apply fungicides as a last resort.

Taro Leaf Blight
(Photo: Scot C. Nelson)

Category 10: Disease Management

Integrated Disease Management Strategies

- **Monitoring:** Regularly inspect crops for early signs of disease.
- **Cultural Practices:** Implement practices that reduce disease incidence, such as proper plant spacing, crop rotation, and maintaining field cleanliness.
- **Chemical Control:** When necessary, apply fungicides and insecticides responsibly, following label instructions to manage disease vectors and infections effectively.
- **Use of Resistant Varieties:** Select taro varieties that are bred for resistance and/or for upland conditions. See Category 2 for more information about varietal selection.

Taro Mosaic Virus
(Photo: Scot C. Nelson)

Cultural Practices for Disease Prevention

- **Soil Health:** Maintain high soil fertility and proper pH to promote healthy plant growth. Healthy plants can replace lost or damaged leaves more quickly.
- **Water Management:** Utilize drip irrigation to keep foliage dry and reduce the spread of waterborne pathogens.
- **Sanitation:** Remove and destroy infected plant debris to reduce inoculum sources in the field. This may not be feasible in larger scale production.
- **Crop Diversity:** Intercropping taro with other types of plants can reduce the severity of disease epidemics. This could be done by alternating rows with other crops. Potential crops: legumes (beans or peas), sweet potatoes, or cassava.

Taro Leaf Spot
(Photo: Scot C. Nelson)

Category 11: Weed Management

Introduction
Weed control is a major challenge in upland taro cultivation, with weeds competing for nutrients, light, and space, potentially reducing crop yields significantly.

Objectives
- To minimize weed competition and maintain high yields and quality
- To implement sustainable weed management practices that reduce the reliance on chemical herbicides.

Cover Cropping for Weed Control
(Photo: GoFarm Hawai'i)

Materials and Tools Available
- Hand tools (hoe, sickle, etc.)
- Mulching materials (organic or synthetic)
- Plastic mulch or woven weed mat fabric
- Cover crop seeds
- Silage tarp for soil occultation
- Herbicides (if necessary)

Strategies for Weed Management
1. **Cultural Control**
   - **Crop Rotation:** Rotate taro with non-host crops that can outcompete or suppress weed growth. This is normally done with a cover crop (See Category 6) planted after harvesting or during a fallow period.
   - **Timely Planting and Harvesting:** Planting taro as soon as conditions allow and timely harvesting can reduce the window of opportunity for weeds to establish. Do not leave soil exposed and bare for prolonged periods as weeds will establish. Tarping (more info below) is a good method to cover bare soil that is not quite ready for planting.
   - **Intercropping:** Sweet potato and nasturtium have been used as ground covers to suppress weeds, usually at small scale.
2. **Mechanical Control**
   - **Hand Weeding and Hoeing:** Effective during the early stages of both taro and weed growth. Making early rounds when weeds are young will be most cost-effective and fastest.
   - **Tillage:** Use shallow tillage to disrupt weed seedlings without affecting the deeper-rooted taro plants.

Category 11: Weed Management

3. **Mulching**
    - **Organic Mulches:** Apply wood chips, grass clippings, or other biomass around taro plants to suppress weeds by blocking sunlight. This is often done at a small scale by hand.
    - **Synthetic Mulches:** Use plastic mulch or woven fabric to cover the soil, which prevents weed emergence and conserves soil moisture. This should be applied before planting but after land preparation and irrigation installation.
    - **Consider Bio-Degradable Mulch:** If available.

4. **Tarping**
    - **Mode of Action:** Use black silage tarps to kill established weeds while also creating an environment to promote germination of weed seeds in the soil.
    - **Preparation:** Prior to laying down the silage tarp, irrigate the field or plan tarp application following sufficient rainfall to encourage weed seeds to germinate.
    - **Application:** Cover the germinated weeds with silage tarps to block sunlight and smother young weeds. The lack of light and trapped heat under the tarp kill the weeds and their seeds, creating a clean slate for planting.
    - **Duration:** Keep the tarp on the field at least 3 weeks. Check periodically to assess the effectiveness and decide when to remove the tarp before planting.

5. **Chemical Control**
    - **Selective Herbicides:** Use herbicides labeled specifically for upland taro cultivation.
    - **Goal 2XL (oxyfluoren):** Offers good pre-emergent control of weeds, when applied within 1 week of planting taro. Optimal field conditions are clean, weed-free soil surfaces.

Silage Tarping for Weed Control
(Photo: GoFarm Hawai‘i)

Wood Chipping for Weed Control
(Photo: GoFarm Hawai‘i)

Category 12: Harvesting Corms

Introduction

Harvesting taro corms is a labor-intensive process that significantly impacts overall production costs. Efficient management of the harvesting process is crucial to minimizing labor expenses and maximizing the quality and yield of the harvest.

Manual Harvesting
(Photo: GoFarm Hawai'i)

Objectives

- To reduce labor costs associated with the harvesting process.
- To maintain high quality and yield of taro corms.
- To optimize the harvesting process through effective strategies, including mechanical harvesting.

Harvesting Strategies and Techniques

1. **Timing the Harvest:**
    - **Age of the Plant:** Typically taro is ready to harvest between 7 to 12 months after planting, depending on variety and growing conditions.
    - **Reduction in Plant Size:** The above ground portion of the plant will get smaller towards the end of the crop cycle. This is because energy is going into corm production. Leaves may begin to droop and turn yellow as indicators of maturity.
    - **Sample a Few Corms:** If uncertain, dig up a few corms from different parts of your field to check maturity. Harvesting too early will result in smaller corms/lower yield and a less developed flavor. Harvesting too late will usually result in lower quality corms, with higher amounts of corm rot.
2. **Preparation for Harvesting:**
    - **Field Drying:** Some farmers choose to dry out fields by turning off water prior to harvesting to make the corms easier to extract. This method must be carefully managed to prevent excessive water loss, which can affect corm quality and yield.
    - **Continuous Irrigation:** Others continue to irrigate until harvest to allow the taro to fully mature, making roots die back naturally, which may also facilitate easier corm extraction.

Category 12: Harvesting Corms

3. **Manual Harvesting Process:**
    - **Extraction:** Remove taro plants from the ground using tools or by hand, which may involve digging or pulling to free the corms. Be careful not to snap off the huli from the corm.
    - **Transportation:** Haul the extracted plants out of the field by carrying the plants by their leaves or using carts or vehicles, depending on farm size and terrain.
    - **Initial Cleaning:** At the field edge or in a designated processing area, remove roots, large soil clumps, and leaves. Some farmers prefer leaving the huli and the main corm intact until after washing or it can be removed at this time.
4. **Mechanical Harvesting Techniques:**
    - **Undercutters/Bed Lifters:** Tractor-mounted undercutters are used to harvest other root crops like carrots or garlic. These types of tools can be used to lift taro up and out of the ground. The main consideration is to be careful not to damage the corms. You need an undercutter and a tractor with enough power to be able to dig deep enough to not cut into the corms.
    - **Modified Potato Harvesters:** Tractor-pulled potato harvesters have been used to harvest taro by configuring them to gently lift the corms from the soil without causing damage. These machines have been effectively demonstrated by University of Hawai'i Extension for commercial taro cultivation.

Undercutter Being Used to Harvest Garlic
(Photo: Theissen Tillage Company)

5. **Washing and Processing:**
    - **Washing:** After initial field cleaning, wash the corms using high-pressure hoses on trays or troughs to remove remaining dirt and debris. Brushes may be needed for hard-to-remove soil.
    - **Separating and Grading:** Cut the huli from the corm (if not already done) and inspect the corms for damage or disease. Considering grading the corms based on size and quality, depending on market demands.

Category 13: Leaf Harvesting

Introduction

Harvesting taro leaves (lau) sustainably is essential for maintaining plant health while providing a continuous supply of leaves for market. This manual outlines best practices for harvesting taro leaves in a way that minimizes harm to the plant and maximizes leaf production and quality.

Objectives

- To implement sustainable leaf harvesting practices that allow for weekly harvests without compromising plant health.
- To ensure high-quality leaves for market by adhering to optimal harvesting and handling techniques.

Taro Just After Leaf Harvest
(Photo: GoFarm Hawai'i)

Materials and Tools Needed

- Sharp, clean cutting tools (e.g., scissors or knives)
- Plastic bags for immediate packaging

Harvesting Techniques

1. **Leaf Selection:**
   - Harvest leaves at a rate that matches the production of new leaves. In most cases that is 1-2 leaves per plant each week, focusing on the second and third youngest leaves. Younger leaves are of higher quality than older leaves.
   - Never harvest the youngest leaf, which is crucial for maintaining the plant's growth and health.
2. **Harvesting Frequency:**
   - Leaf harvesting can begin as soon as leaves are at an acceptable size for your customer or preference. This is usually around 3 months after planting.
   - Maintain a weekly harvesting schedule to allow the plant to continue producing new leaves, while not allowing leaves to get older and tougher.
3. **Cutting Technique:**
   - Harvesting leaves will be the most labor-intensive activity for this crop so it is important to work efficiently.
   - There are many different techniques for how to cut leaves efficiently.
   - One technique that was observed by some of the faster harvesters is described here. It requires holding and cutting the leaf with a single hand, which will require practice.

Category 13: Leaf Harvesting

3. Cutting Technique (Cont.):

- *Assuming harvester is right hand dominant:*
  i. *Stand so the taro to be harvested is to the right of your body*
  ii. *Hold the knife with your right hand, thumb behind the blade*
  iii. *Using only your right hand cut thru the stem, you need to hold the stem while cutting thru.*
  iv. *Transfer the cut leaf to left hand*
  v. *Give your left hand a quick shake to remove any excess water*
  vi. *Continue this procedure until left hand is full of leaves*
- Use sharp and clean cutting tools to make precise cuts, removing leaves by cutting through the stem, close to the leaf.
- Try to cut close to leaf to avoid excessive stem portions on the harvested leaves.
- Ensure no water is on the leaves after cutting.

Handling and Packaging

1. **Immediate Bagging:**
   - After harvesting, immediately place the harvested leaves into plastic bags to maintain freshness and reduce moisture loss.
   - Handle leaves gently to avoid bruising or tearing, which can degrade quality and appearance.
2. **Weighing and Packing:**
   - Weigh the filled plastic bags to ensure each bag meets the market standards. Most growers market a 20-pound bag for wholesale markets.
   - Seal the bags to prevent contamination and further moisture loss.

Cultivar Selection for Optimal Leaf Production

- Select cultivars known for their robust leaf production and resistance to common pests and diseases. Varieties like ‘Bun Long’ are preferred for their large, tender leaves suitable for culinary use. More information is provided in Category 3.
- New cultivars with resistance to diseases such as taro leaf blight can offer additional benefits, including reduced pesticide use and more consistent yields.

Market Preparation

- **Transportation:** Transport the packed leaves to the market as soon as possible after harvesting to maintain freshness and quality.
- **Cooling:** If packed leaves are not sold to market the same day, they should be refrigerated to maintain freshness.

Category 14: Cost of Production for Corms

Understanding your cost of production is critical to understanding if your crop will be profitable or not. In this exercise, we will calculate the production costs for a 100-foot row of taro dedicated to corm production. We will estimate these costs using the guidelines provided in the cultivation manual.

CROP INFORMATION	
Row Length	100 ft
Plant Spacing (ft)	2 ft
Planting to Harvest (days)	300
Length of Crop Cycle (days)	300

PLANTING INPUTS and AMENDMENTS	COST PER 100 FT ROW
Weed Mat	$28.00
Irrigation Tubing	$10.00
Pre-Plant Compost	$6.00
Pre-Plant Meat and Bone Meal (MBM)	$7.50
Pre-Plant Gypsum	$4.95

FERTILIZER COSTS	COST PER 100 FT ROW
MBM 3 Months After Planting	$7.50
MBM 6 Months After Planting	$7.50
Potash (two applications)	$2.50
Pesticides	$15.00

Category 14: Cost of Production for Corms

WATER USAGE and COSTS	
Irrigation Water Costs	$4.50/1000 Gallons (Avg. Potable Rate)
Weekly Water Requirement	200 gal/100 ft. row
Total Cost of Water	$38.57

LABOR INPUTS	ESTIMATED HOURS
Bedding/Amending/Installing	4
Huli Collection and Planting	4
Fertilizing and Applying Pesticides	1.5
Weeding	8
Harvesting and Washing	6

Total Input Costs	**$127.52**
Average Weight of Corm	**3.0 lbs**
Total Harvest	**100 lbs**
Cost of Production	**$1.27/lb**

Calculate the cost of production by summing all input costs and dividing by the harvest yield. We calculated a cost of taro crop in this example to be $1.27/lb which is under the retail market rate, indicating there is economic viability.

It should be noted that this calculation does not account for labor costs. Paying for labor would result in a significantly higher cost, primarily due to the extensive labor hours factored into our estimates. These hours are disproportionately high compared to commercial operations. For instance, with an appropriate tractor setup, tasks such as bedding, installing, and amending could be done all at once in minutes, rather than the four hours estimated in our manual. This adjustment is vital for scalability and economic feasibility of larger farming operations.

Category 15: Cost of Production for Taro Leaf

In this exercise, we will calculate the production costs for a 100-foot row of taro for leaf production. The majority of the input costs are the same as we used for the corm example (See Category 14) and will not be shown in detail in this example. The main difference in leaf farming is the repeated harvest rounds, in this case we conservatively estimated a harvest every 1.5 weeks.

CROP INFORMATION	
Row Length	100 ft
Plant Spacing (ft)	2 ft
Planting to Harvest (days)	75
Length of Crop Cycle (days)	300
Number of Harvest Rounds (1 harvest/1.5 weeks)	21

LABOR INPUTS	ESTIMATED HOURS
Bedding/Amending/Installing	4
Huli Collections and Planting	6
Fertilizing and Applying Pesticides	1.5
Weeding	8
Harvesting (1 hour per round)	21

Category 15: Cost of Production for Taro Leaf

Total Input Costs (See Category 14)	$227.52
Average Leaf Weight per Harvest	20 lbs
Total Harvest	420 lbs
Cost of Production Without Labor	$0.54/lb
Cost of Labor (40.5 hrs X $20/hr)	$1.92/lb
Total Cost of Production	$2.46/lb

To calculate the cost of production, we sum all input and labor costs and divide by the total harvest yield. In this example, we calculated the cost of taro leaf to be $2.46 per pound, which is less than its retail price. Including labor costs highlights their significant impact on total costs; for instance, it takes an estimated one hour to harvest 20 pounds of leaf. With labor costs at $20 per hour, this translates to $1 per pound of leaf, constituting nearly 40% of the total production cost.

Understanding these costs is crucial for decision-making aimed at enhancing farm viability. For instance, as harvesting accounts for 40% of total expenses, any improvements in harvesting efficiency can significantly impact the bottom line. This insight guides strategic decisions to optimize operations and increase profitability.

Conclusion

The “Upland Taro Cultivation Manual” is crafted to support and enhance the cultivation of taro in Hawaii, a crop of immense cultural significance. This manual provides farmers with detailed, practical instructions for each phase of taro farming, from soil preparation to harvesting, focusing on sustainable methods. The comprehensive guidance aims to help local farmers improve their crop quality and yields while better understanding the cost and economics of commercial production. By adopting these practices, farmers can contribute to the sustainable growth of taro production, ensuring taro remains a cornerstone of Hawaii’s agricultural and cultural heritage.

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Taro Harvests at GoFarm Hawai‘i Training Sites
(Photos: GoFarm Hawai‘i)