Growing Upland Taro

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"You cannot grow taro on dry land. It's called upland taro and you need water to grow it."

Masashi 'Cowboy' Otsuka
Molokai Kupuna and Hawaiian Taro Expert

Taro needs water to grow, whether in wetland or dryland systems.

Taro is the most significant plant in Hawaiian culture, not only as the most important staple, but is tied to the creation chant of the Hawaiian people. It's believed that about a handful of taro cultivars were brought to Hawaii by the early Polynesian voyagers, of which over three hundred cultivars evolved.

Most of the taro grown in Hawaii today is in wetland or submerged culture. However, in ancient times upland taro was commonly grown in many areas of the state with reliable rainfall. Areas on the island of Hawaii where upland taro was well adapted include Hamakua, Puna, Ka'u, Kohala, and Kona.

With the decrease and unreliability of sufficient water flow by diversions coupled with limited areas to cultivate wetland taro, the production of upland taro is viewed as an alternative to wetland production. However, in many respects, wetland and upland taro are distinct products in terms of corm quality and poi characteristics, and examples include relative corm density or dry matter content, and poi souring characteristics.

Upland taro is better adapted to uses such as table taro and kulolo, and usually produces poi taro of a lower quality both in viscosity and acceptable poi souring characteristics compared to wetland taro, since the fermentation process can take a different path.

Upland taro in Ho'olehua, Molokai grown in plastic mulch under a wide row system to facilitate cultivation by tractors. Weed control is a major challenge.

However, if grown with the utmost of care and nurturing, it can produce poi of fairly high quality that can even impress an experienced wetland taro grower or poi eater. Upland taro has many potential uses, including candies, snacks, and nutritional and probiotic drinks.

There are many methods of growing upland taro, including traditional systems utilizing heavy compost in a living, slow-release organic system to modern high-input production systems, as well as hybrid systems utilizing the best of both growing systems. These options should be thoroughly investigated prior to planting, considering soil and plant health over the long term, labor requirements, and above all, cost and returns in a quadruple bottom line.

Modern production systems include integration of mechanical transplanting of huli, drip irrigation utilizing water and soil sensors, ferti-gation or injecting nutrients and plant inputs through drip systems, and ongoing soil and tissue monitoring, among other cutting-edge production technologies.

High quality upland taro can be produced with consistency in areas of high light intensity with a reliable water source. Under these conditions, yields exceeding 35,000 pounds per acre can be achieved.

The key to producing high quality taro is to grow a healthy plant in a stable growing environment. While easier said than done, adjusting the system to changing environmental conditions is the key. The most common problem in growing upland taro is neglect, including inconsistent watering, nutrient imbalances, and poor cultural management, including the lack of wind protection and poor weed control. The taro plant can adjust to the environment in a sustainable or subsistence system, but the end result will be a lower relative yield and sometimes quality.

Stress is the destroyer of taro and will predispose the plants to less than ideal growing conditions, manifesting itself in many ways, including susceptibility to attacks by insects and arthropods, and also diseases, including poor or imbalanced nutrition.

Two ohana of Maui Lehua, believed to be a hybrid of Lehua maoli and Pi'i ali'i.

Huli Production

Growing taro starts by having sufficient quantities of healthy taro huli or planting material in order to plant taro consistently to supply arranged markets. Huli is the upright stem between the leaf and the corm and includes a piece of the corm attached where roots emerge.

Huli starts as eyes or makamaka and sprouts into oha or keiki growing off the makua or mother plant.

Growing taro starts with healthy, disease-free huli – Maui Lehua

Each line on a corm has an eye or makamaka that has the ability to grow into an oha, although many may be blind or dormant and will not form into oha. Each variety is different in their ability to produce oha. Some varieties, such as Mana ulu and Lehua maoli can produce up to 25 oha or off-shoots per plant in Ho'olehua, while others such as Mana ke'oke'o may produce only 1 or 2 oha.

Taro huli cannot be purchased at a seed store; it must be produced through vegetative means from existing taro production. Huli can either be removed from growing plants or secured when harvested. Some taro plants can be produced through micro-propagation, but experience has shown that micro-propagules can have a high incidence of mutations and mature plants can have different characteristics its parent, including corm color and plant habit.

Collecting huli, then planting and propagating more huli takes time. One option is to create a huli bank by replanting every propagule harvested that's not sold, including very small oha. Place all propagules in a furrow one next to another in a continuous chain and cover lightly with soil. The row should be irrigated on a consistent basis. Plants can be removed as soon as they reach an acceptable size for replanting.

Another method is to plant medium to large huli at 6 inch spacing and fertilize well. After a couple months, chop the makua to activate the oha into rapid growth. Dig out plants when they reach acceptable size for replanting. Another option is to remove huli of adequate size during production, careful to allow wounds to seal over. It may not be a good idea to remove huli from mature plants during rainy months due to the possibility of creating an entry way for disease.

You can never have too much huli. Without huli, you cannot plant or harvest taro. Maui Lehua

Sorting huli by size based on bottom diameter is an important consideration to improve uniformity in corm size when harvesting, and can also affect days to harvest by creating harvest increments within a field planted at the same time.

A 'huli' bank grown in a garden by covering small corms after a harvest. This allows for ready access to huli and can also be used for leaf production.

Weed Control

'One year of weeds, seven years of seeds'

Weed control is the greatest challenge in upland taro, and much time and labor can be spent combatting weeds. Weeds compete with taro for light, nutrients, water, and carbon dioxide, and can substantially increase the cost of growing taro. Some weeds can act as a reservoir for insects including aphids and mites that can become serious pests of taro.

A well thought-out strategy must be employed to minimize labor spent controlling weeds. Strategies include early and multiple field cultivation, herbicide application, flaming, using plastic mulch and weed mats to suppress the majority of weeds, and pre-sprouting then killing weeds by flaming or herbicides.

Weed control also involves controlling weeds upwind from new planting fields, such as field cultivation months prior to planting to decrease weed seed populations or 'weed load' in the ground. After weed seeds are minimized in the field through cultivation, another strategy called 'sterile seed bed' involves preparing fields for planting, including the incorporation of fertilizers and amendments. Irrigate the field to sprout weeds. After weeds emerge, either burn weeds with a flamer or spray with a contact or systemic herbicide to kill the weeds. If using a flamer, it's important to treat weeds when very small such as less than ½ inch tall or in the three-leaf stage otherwise larger, stiffer weeds will not be killed.

Sometimes the only way to preserve a special variety is by propagating and growing them in flats. A Pi'i ali'i mutation with pink-fleshed corms.

If using a flamer near a drip irrigation system, be sure to remove drip irrigation lines prior to flaming or end up melting your drip lines. After weeds show signs of dying, plant huli in rows trying to not to disturb the ground. Disturbing soil will bring new weed seeds to the surface and require additional weeding. Weed control cannot be overstressed, because many upland taro fields have been lost to weeds.

Maui Lehua grown in a furrow system. Water stays in the center of furrows close to the huli, and roots grow deeper in the ground, protected from the surface heat.

It's very important to control weeds when very small since procrastinating will not only increase the labor involved, but the energy involved in pulling out each weed. Kristen Kimbell, author of the book, 'The Dirty Life' wrote that the best time to control weeds is 'in the white thread stage' and this is valuable advice.

There are many tools used to stir the soil to control very small weeds, but weeds around the huli must be tended by hand. The use of a stirrup or hula hoe is an efficient way to control weeds between rows since it requires less energy compared to common hoes that require lifting and hitting the ground to dig out weeds. The use of wire weeders works well within rows, either hand or long handled types. However, if weeds are older than a week old, these tools may not work well and may require heavier hoes and additional energy to accomplish the task.

It's important to minimize deep weeding and mechanical cultivation after plants have been well established since root damage can open entry ways for disease. The use of rototillers between rows should only be used early in the growth of plants. Later rototilling can damage feeder roots, many of which can fill the entire length and breadth between plant rows.

Huli spacing also affects weed control. Closer spacing of 12 to 14 inches will allow plant canopies to shade the ground faster, allowing for quicker weed suppression. Planting large, fresh, healthy huli is very important so individual plants can stand their ground earlier, and provide a strong, large canopy to shade out weed competition.

Plant Spacing

The spacing between plants, both in rows and between rows, is an important planning consideration. Close spacing limits air circulation and create environments favorable for pests, including arthropods, insects, and will influence mature corm size and yields.

Southern Blight Sclerotium rolfsii is an important disease of lowland production throughout the Pacific

According to retired U.H. plant pathologist Dr. Eduardo Trujillo, densities higher than 7000 plants per acre are favorable for the proliferation of Southern Blight (Sclerotium rolfsii), a surface rot of plant and corm prevalent in the Pacific. Poor air circulation can also lead to the rapid spread of Taro Leaf Blight (Phytophthora colocasiae), the most destructive disease of taro, when wet, cold overcast conditions include Kona weather with no wind. Aphids, taro leaf hoppers, and mites can spread rapidly with poor air circulation.

Plant spacing must be considered in the overall scheme of things including expected yields per acre, size of individual corms, labor requirements, market demands, and equipment available for harvesting, among other things.

With 7000 plants per acre as the target, spacing configuration can include 3' x 2', 1.5' X 4' or 1' x 6, and in many cases are determined by tractor tire spacing or market demands for a certain corm size and weight. In-row spacing can range from 16-24 inches, with between-row spacing of 3 to 6 feet.

When utilizing drip irrigation, a single or double row can be planted on each planting line. However, experience has shown that double row systems can be problematic since vigorous growing varieties with large root systems can choke drip irrigation lines, decreasing water flow to the remainder of the row.

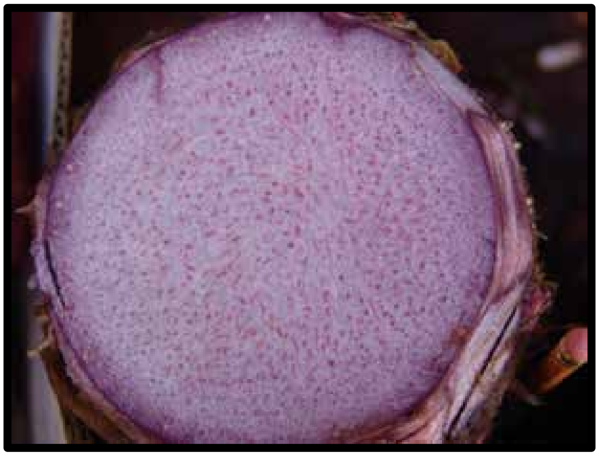
Soil Preparation and Nutrient Management

There are many options in preparing land prior to planting, including furrow and flat land systems utilizing large amounts of organic mulch and compost, plastic mulch and also weed mat between rows. Each system has its pros and cons, affecting not only water distribution and growth, but also quality and yield.

Taro Leaf Blight Phytophthora colocasiae, is the most destructive diseases of taro, and favors calm, cold, wet overcast conditions.

In Ho'olehua, a hard pan, also referred to in soil terminology as the bT horizon, or the horizon of clay accumulation can be found 1-2 feet below the surface, and can be advantageous in creating a wet land type of growing system by holding water near the surface. However, it's important that the soil be aerated to prevent anaerobic conditions detrimental to good upland taro growth. Again, taro can adjust to whatever environment is presented as long as reliable water in the way of rainfall or irrigation is available. Under stressed conditions, plants will produce smaller corms and sometimes less oha.

Taro responds well to fertilization, and it's important to collect soil samples in order to set benchmarks for a nutrient management program. Most of the fertilizer or inputs, including organic matter should be incorporated prior to planting. Under a high-input, high-yield drip irrigation production scenario, the majority of nitrogen required can be injected through irrigation water through 50 to 70 percent of the growing season.



Although commercial poi markets prefer Lehua taro varieties with lilac corms, there are more white and pink Hawaiian taro varieties than there are lilac varieties, many of which are high quality with unique tastes.

Nitrogen requirements can range from 350 to 500 pounds per acre, depending on production goals, individual corm size envisioned and yields predicted. In a 9-month production system, nitrogen would be delivered over a 6 month or 180 day period or less. For example, at an average of 2 pounds of nitrogen per acre per day, 360 pounds can be delivered to plants in a crop season through a constant-feed fertigation system. Again, the targeted size of corms at harvest should be determined by market demands.

In the Law of the Minimum, the shortage of one nutrient can affect the ultimate yield of the crop. While it's important to have all required nutrients available for the crop at the right amounts, an excess of one nutrient can affect the availability of another, and this can be seen when over-fertilizing with Nitrogen.

Rapid growth in response to Nitrogen uptake can create a shortage of other key nutrients, including Calcium. Thin cell walls are produced due to Calcium deficiency, an important component of cell walls in leaves, and cells can burst from windy conditions, for example, and predispose leaves to foliar diseases.

Seasonal Variability

Seasonal variability can add another dimension to the idiosyncrasies of your production system and present new challenges. For example, there are higher risks of fungal diseases in rainy weather and winter months, while summer months present more insect and arthropod challenges, affecting projected yields, and also supply and demand for the product.

Light and temperature levels can also affect plant growth, production quality and yields, as well as insect and disease. Production, no matter how well managed and monitored, is never the same as many variables can affect the 'happiness' of taro. Taking one season at a time, and being vigilant in managing the crop is critical.

Harvesting leaves, then corms for shipment to Maui for processing into taro burgers. 2011

During rainy weather in both spring and winter, weeds are an ongoing challenge that must be dealt with. There appears to be ideal seasons for the growing of taro, from early Spring into Winter but does little to facilitate the production of taro year-round. During the short days of winter, plants grow slower and have difficulty taking up fertilizer, especially Phosphorus. Less than ideal weather conditions for growth and ideal conditions for disease during rainy months can predispose plants to stress, creating ideal conditions for disease that can affect corm quality.

Leaf Production

Leaf production and corm production are different 'animals' and should not be mixed or integrated. In leaf production, there are different cultivars used, with Bun Long Woo as the dominant variety. However, there are many other varieties that could be utilized including Palauan and Hawaiian varieties. Hawaiian varieties utilized for leaf production have included Lehua, Mana, Piko, and Apuwai. Later-maturing varieties will produce leaves over a longer season than early-maturing varieties.

Other considerations include leaf tenderness or the lack of stringiness, and keeping quality. As plants get older, leaf size will decrease and some may become stringy, affecting marketability. Weed control is also a bigger challenge in leaf production compared to corm production, and some farms will cover entire rows between plants with weed mat or weed barrier.

There are many strategies utilized in how many leaves to harvest per plant. Leaves can be harvested on a monthly basis with the center unfurled leaf left back and the remaining harvested. Some farmers will only harvest two to three of the first fully opened leaves, leaving the remaining to support active growth.

Bun Long Woo is the most common variety used for leaf production in Hawaii.

It's also important to consider nutrient replacement when intensively harvesting leaves versus harvesting under a more sustainable production system. Each time you harvest leaves, you're removing nutrients from the system that will need to be replaced in order minimize plant stress and optimize plant and leaf recovery and growth.

A phenomena called 'hard leaf' occurs under windy, high-light and high-temperature conditions creating a stringy, hard leaf that can double the cooking time as well as the quality of the cooked product, including laulau and luau, and is more prominent during summer months. Windy conditions can increase the production of fiber as plants adjust to this condition, and can be aggravated by a nutrient imbalances created by the plant's higher demand for nutrients.

Disease Management

Taro diseases can be broken down into leaf, corm, and root diseases with many interconnections, and a whole book can be dedicated to this topic. In upland systems, crop rotation, organic matter build-up, and long-term soil health are important considerations in the prevention of taro diseases. 'For everything, there is a season', and many problems are seasonal. Knowing what each season brings in the way of challenges is the start in anticipating a problem and preparing for it.

Root-knot nematodes are a major problem in upland taro production, and can adversely affect yield and quality of corm and leaf. Some soil types are more amenable to root-knot nematode proliferation, and are further complicated by the nematode species. The red pineapple soils or Oxisols are an especially good media for the rapid explosion of root-knot nematode populations, especially the Javanica root-knot nematode *Meloidegyne javanica* while organic soils with a diversity of microorganisms are better balanced to mitigate nematode damage.

Varieties grown for leaves: Palauan, and Bun Long Woo, far left. The Palauan started off slowly, but soon surpassed Bun Long Woo.

Well planned crop rotations utilizing nematode-resistant species, fallow, and the use of cover and green manure crops are all part of the farmer's tool box. There are costs, in labor, supplies, and time that must be considered. The addition of organic matter, either through importing material or through the growing of high organic matter species in a rotation system should be an ongoing strategy.

Taro requires consistent water to grow tall and strong. The author in his element.

Water Management

Water management is a critical consideration, especially in adjusting the amount of water required for each season. One strategy is to break the year down into four seasons based on Equinoxes (March 21 and September 21) and Solstices (June 21 and December 21).

These are key times for evaluate water delivery in two areas, frequency and duration. In hotter times of the year, irrigation maybe required twice a day versus once a day, while in winter months, once a day may be sufficient.

For example, in pan evaporation trials on Molokai it was determined that 2 acre inches was required to replace losses from evapotranspiration. Under these extreme conditions of high temperatures and high wind impacts, over 54,000 gallons per acre per week was required to replace water losses. Plant spacing also had an impact on water losses, as well as the use of plastic mulch.

One area requiring more research is planting in furrows in a drip system, keeping water deeper in the soil profile and away from the soil surface. Soil and air temperatures also affect plant metabolic rates.

Taro is not well adapted to high-temperature, lowland conditions since its native to more upland weather with cooler climates and a larger day-night temperature differential. Under extreme conditions, frequent irrigation of more than twice daily may be utilized as a strategy to cool plants off in order to slow the metabolic rate and minimize stress that could lead to internal corm breakdown or worse.

Keeping water clean and free from algae and other contaminants in water is a major challenge. The use of a filtration system with a 150 to 200 mesh filter is required to prevent drip lines from clogging and must be cleaned regularly, but even under this regimen, irrigation systems can clog to the point where very little water reaches the plant especially late in its growth cycle.

Harvesting a mixture of taro varieties, including hybrids and Hawaiian varieties.

Determining maturity is based on many factors. Plants will reach their peak vegetative growth and is determined by variety, height, and age. They will then start to drop back in growth as the corm enlarges. In upland systems, the majority of the corm will form out of the ground.

One determination is doming at the top of the corm where it attaches to the huli. As they reach maturity, the top of the corm will start to constrict forming a dome. Under hot summer conditions, some farmers will harvest early when plants just start to dome, while in cooler seasons they will allow corms to dome to the extent where the huli diameter is the size of a silver dollar. Field and increment size as well as markets are also considerations since some fields may take a while to harvest, while in high demand periods, large fields will be harvested.

Harvesting Corms

Harvesting is the highest labor cost, probably exceeding 50 percent of the cost of production since most of it is hand labor. This includes digging, transporting, cleaning, washing, sorting, grading and packing. A harvesting continuum or flow needs to be developed to minimize the cost and the amount of 'touches' to the corm. Some farmers will haul the crop out of the field while others will field-process and pack, and each have its pros and cons. It's a matter of convenience and preference, as well as having a comfortable place to work, especially in hot summer months.

Some farmers will dry out fields by turning off water prior to harvesting, while others will continue to irrigate and allow the crop to mature so roots die back to facilitate easy extraction of corms from the grounds. Since plants have high water content, drying out fields may create high water loss and affect corm quality and yield.

Harvesting includes hauling plants out of the field, cutting leaves, and cleaning roots before washing taro.

There are trade-offs in each harvesting system and must be well thought out. There are many options, including harvesting only the mother plant or Makua and leaving oha to mature for another couple of months to fill out and realize a higher total yield, but will also require more labor to harvest twice.

One harvesting sequence includes the following:

1. Extract plants from the ground by digging, pulling, or kicking

2. Haul out of the field by its leaves
3. Remove roots, large soil clumps, and leaves, leaving huli and corm intact
4. Wash corms with high pressure water hose in a large trough
5. Sever huli from corm, and separate into grades
6. Pack in onion bags; weigh, mark and stack
7. Ready for shipment

Depending on market demands, there may be additional grading of taro by size.

Recycling Huli

The processing of taro huli for field planting including collecting, trimming, grading, and replanting must take place soon after harvest. As a consequence, new fields must be prepared for planting prior to harvesting. Huli is valuable and must be treated as such, and has a short post-harvest life.

Eleele makoko, an excellent upland taro variety from Kona with purple corms.

Most huli should be returned to the ground within a week or it will deteriorate, facilitating replacement of rotted huli by replanting newly planted fields. Since planting huli is another high labor job, care must be exercised in keeping huli in good condition prior to planting. This includes storing in a cool, shady place with good air circulation.

Poi produced from a mixture of white, pink, and purple upland taro, ready for consumption

In closing, this is far from an exhaustive treatise in the growing of upland taro, since much more is involved in growing this culturally important crop. More knowledge will come when you plant the crop and recall what you did right and what you did wrong, and fine tune from there.

Queen Emma's Taro Patch

Queen Emma is best known for establishing Queens Hospital to serve the Hawaiian people, but few know that she was quite knowledgeable about the culture of taro. The wife of Kamehameha IV, Queen Emma lived from 1836 to 1885 and was considered one of the most influential queens of the Hawaiian Monarchy. In one of her writings found in the Bishop Museum archives entitled 'Observations on Varieties and Culture of Taro', she discusses constructing a lo'i, the different taro varieties, planting techniques, and harvesting.

Outlining the steps involved in making a lo'i or taro patch, she states, "*The banks are covered with mats and beaten with stalks of coconut leaves or smooth pieces of heavy wood until water tight. The loose soil is strewn on the bottom as level as possible and about a foot thick. The water was let in, and when it covers the soil about 6 or 8 inches, as many persons and oxen as can be procured enter it and trample it into soft, almost liquid, mud in order to amalgamate the soil and allow it to find its own level and close any leaks there may be in the bottom… refreshments and merry making follow after this part of the performance, and by the next day the patch was ready for planting*."

Taro planting material or huli were hard to find and had to be purchased from others. "*Formerly they were given reciprocally, but now they have to be purchased, unless supplied by some rich and kind friend*." They would buy rows of plants in the patch, called lalani or even whole patches for huli. She understood fertility and mentions "*when the soil became impoverished from frequent use …the mud is collected in heaps, called pupu kolea and three or more plants are placed on each hill. When the patch is still more impoverished, for it's a very exhausting crop, larger heaps have to be formed and planted almost dry, with hills covered with rushes (sedges) 15 or 20 to a bed, as it is called pu'epu'e*." The plants growing in a lo'i would degenerate and become small and weak, so they would plant the huli *"into wet vegetable soil"* to regenerate them, and return them to the lo'i. The same variety can grow much larger in soil, and by starting with large huli, a higher yield can be realized. This was also a strategy to get rid of water-borne rots and diseases.

In securing huli, she mentions that "*plants should be selected from the varieties best adapted to the locality and nature of the soil*." Queen Emma mentions her favorite taro varieties and proceeds to name over 40 varieties. She indicated that "*Piko kea and Ipu-o-Lono were the most productive.*" Next came the hardy Apuwai, then Haokea, Piko (Piko Ke'oke'o), the three Ka'i, and the tabued dark Pi'i Ali'i. Others included Eleele naioea, and "the old favorite Lihilihimolina", which was thought to be extinct but recently found in Hanapepe, Kauai. Of those mentioned, about half are either not found today or are synonyms for some of the existing ones.

She also mentions that after cooking taro in the imu, it was eaten as-is in many places, while other places were pounded into poi. She observed climatic differences in the maturing of taro, noting that taro grown in Honolulu matured much quicker that those grown in the valleys. Her writings are very detailed and attest to the deep understanding of taro growing by the ancient Hawaiians, even royalty. Today, the more we learn about taro, the more we realize how little we know.

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Well, that's it for this quarter! I realize after growing upland taro for over 2 decades that I think I know a little about taro. As we head out of the craziest summer in memory with extremely hot and humid weather followed by torrential rains, we can only speculate what is yet to come. Stick around for more…

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