# *Thinking Like a Papaya*

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*"Under conditions of optimum moisture, sunlight, and temperature, papaya trees make stocky growth, mature at an early age, and produce an abundance of fruits…the lack of sunlight, and probably of warmth, during the cool season in Hawaii is usually reflected in retarded growth and in the setting and maturing of fruits. This is particularly true at high elevations and in cloudy, rainy localities."*

*Papaya Production in the Hawaiian Islands*
*Jones, Storey, Parris, and Holdaway - 1941*

Growing a crop that takes nine months to first harvest requires planning, knowledge, and diligence. It's about visualizing the ideal conditions required to grow papaya, understanding cause and effect, and committed to managing your crop.

*One way of approaching this is by thinking like a papaya, if you can envision this. The above quote is a good starting point to delve into this crop. What makes this crop tick, and what does it need to not only grow, but thrive?*

The lack of Papaya Ringspot Virus enables Molokai farmers to grow this crop under organic conditions, but with this ethic of farming comes special growing challenges in addressing nutritional needs and facing pest control challenges head-on.

*Holistic Production*

When you approach growing from a holistic perspective, it's very difficult to categorize or pigeon-hole things because everything is connected.

*Sunrise Papaya ready for first harvest. Ho'olehua, Molokai*

Putting all of these variables into an organized rational strategy that includes understanding how the different variables interact is a real challenge.

Such a system has interacting and constantly changing moving parts that

you are challenged to split hairs in making decisions. The first step in this exercise is to identify all the variables involved in growing papaya, and getting a grasp of how they interact. This exercise can be applied to any crop.

One thing I've learned about working with farmers is that redundancy is good, so this newsletter mentions a lot of stuff more than once, and part of this is due to the connectedness of the different variables.

*Sources of Information*

Your information is only as good as its source. The UH CTAHR Publications site is a good starting point for research-based information and most of the pubs are free. Here's how to connect:

https://www.ctahr.hawaii.edu/site/Info.aspx

Just punch in 'papaya' and all papaya-related publications will appear: If you're growing Sunrise papaya, you'll want to read the publication, 'Sunrise Solo, a Different Colored Solo Papaya' as a starting point. This publication was released in 1968 and written by Richard Hamilton and Phil Ito, creators of the Sunrise papaya. Here's a copy of the publication:

https://www.ctahr.hawaii.edu/oc/freepubs/pdf/C2-69.pdf

This gives an overview of Sunrise Solo Papaya characteristics and a little about this variety. Gleaning from this publication, "under good growing conditions, plants will bear first fruits 3 feet off the ground, and fruit will have average total dissolved solids of 15.5%." This is a measure of fruit sweetness, also called Brix, and Sunrise has a reputation as one of the sweetest papaya varieties. This variety also sets fruit very heavily at the start then declines, setting 2 to 2.5 fruit per week.

*Sunrise Solo Papaya - Fruit shape and uniformity shows up in the box and on the store shelf, and sells your product. It's also the face of your farm if you have a sticker on it.*

Fruit size ranged from 15 ounces at Poamoho Research Station near Oahu's North Shore to 22 ounces in Malama Ki Research Station near Puna on the Big Island. What this last fact is saying is that climate, soil, and nutrition can affect fruit size. Malama Ki is in fairly new lava soil and Poamoho has weathered red soil or Oxisol similar to Hoolehua.

Elevation maybe a factor in how flowers react to weather, both hot and cold, since these two research stations are located at very different elevations. Poamoho is around the same elevation as Ho'olehua at 550 to 700 feet while Malama Ki is located at 300 feet.

"Male sterility", where the normal hermaphrodite flowers only develop male parts resulting in 'skips' or no fruits was more pronounced at Poamoho than at Malama Ki during the late summer from July to October. Carpelloidy or cat-facing is a concern during colder months, producing unmarketable fruits resembling deformed female fruits.

This publication also mentions that plant size or plant stretching can be controlled by the amount of water given, and this will be touched on later. All this information are guide posts or measures used to determine if you're hitting the mark in your production system or not.

> ***"If you're not making mistakes, then you're not doing anything. I'm positive that a doer makes mistakes."***
>
> ***John Wooden***

*Knowledge*

Reading papaya publications is one source of information, but you still need to have a basic knowledge of agriculture and how plants grow. Without this, your only option is 'Learn fast while you make mistakes' or 'fall forward' meaning you're making mistakes but moving forward. Where do you start as a farmer to increase knowledge of your crop? By having a basic understanding of how your crop grows as well as its likes and dislikes by growing it for a season or more.

Much of this is life-long learning because, like your crop, you keep growing. It's about reading as much as you can about papaya. A good publication released in 1941 is called 'Papaya Production in the Hawaiian Islands' gives a good overview, although a lot of the information is dated.

https://www.ctahr.hawaii.edu/oc/freepubs/pdf/B-87.pdf

Dealing with inherent challenges starts with a review of old research because some problems never disappear. A more recent publication called 'Papaya Production in Hawaii' features information added by Extension Agents and Specialists:

https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-103.pdf

*Walking your field to look for problem areas is one thing; doing something about it is another. Freeman Farm.*

Molokai farmers are constantly dealing with fruit skips, misshapen fruit, and carpellody or cat facing, and have continued to select plants that exhibit less of these tendencies. At the crux of the problem is the fact that Ho'olehua is too hot and dry in the hot season, especially on hot, humid days and too cold on many days in the cool season for optimal growth.

Selection of individual plants suited to these conditions is critical. This is done by selecting trees that bear fruit throughout the year and show little cat-facing and by using the seed of the fruit from these trees for replanting.

Based on the experience of Hilo Extension Agent Melvin Nishina, who worked closely with the Puna papaya growers for decades, temperatures should generally not drop below 60 degrees F or exceed 90 degrees F to minimize fruit deformity, so selecting superior trees during extreme conditions is critical.

You can't change the weather, only the production system. How do you build upon your knowledge base? Where do you start in order to help your papaya grow better? Having a solid base of knowledge in farming papaya is critical. Having relevant information is also very important.

Hawaii growers produce papaya varieties that are unique to Hawaii, although Brazil built their papaya industry upon one of the Hawaii papaya varieties, Sunset, a sibling to Sunrise. Some of this information may be transferable but must still be vetted or field-tested first.

The other important source of information is other papaya farmers, especially in your area, but also in other parts of the state. I cannot say enough about working with other papaya farmers to build on each other's knowledge, and sharing the good and the bad. This synergism is important as farmers move forward together. The strength of farming in Ho'olehua is in interdependence.

*Taiwanese Papaya Red 14, female (L) and hermaphrodite (R). Notice skips on the right tree.*

### *Seedling Production*

It all starts with seed, including selecting, cleaning, and drying seed. Before storing seed, removing the sarcotesta or the clear sac around the seed will allow water to penetrate the seed coat more readily to allow the process of germination.

If not removed, germination will be erratic. Drying seed also allows the seed coat to harden with fine hairline cracks that allow seeds to imbibe or absorb water. If fresh seeds aren't used for planting, properly storing dried seeds is important by refrigerating.

Aside from soil building and field preparation prior to planting, growing superior seedlings is an important starting point. Like managing a miniature papaya farm, good soil tilth, proper nutrition, and the right amount of water managed on a daily basis are some of the points a good papaya seedling grower needs to focus on.

There are many ways to produce seedlings, and cost and labor are the first considerations. Methods include direct seeding, growing in flats then transplanting to a cell at the two-leaf stage, and germinating in cells. Seeds germinate slowly, from 12-20 days. Soaking seeds overnight in water will also enhance germination.

*Seedling production requires daily management to grow the best seedlings possible. Pak Choy and red lettuce.*

When planting in cells, managing the microclimate in the cell is critical to optimal growth with limited swings in moisture levels and a steady supply of nutrients either incorporated in media prior to seeding or liquid-fed overhead.

Seedlings are usually transplanted 1½ to 2 months after germination, around the 8-12 leaf stage or about 8 inches high. The careful growing of seedlings cannot be overemphasized. Gradually hardening seedlings is important prior to transplanting especially in extreme hot weather.

Coordinating field planting with the ideal seedling takes practice so seedlings are not pot-bound. In this situation, seedlings will sit in the field before taking off and any slowed growth will manifest itself in the end product. If you're transplanting pot-bound seedlings, you're probably wasting your time.

*Observation*

Walking the field on a regular basis is a good habit to cultivate, while learning as much as possible to better understand and manage your crop. Keen observation helps you understand cause and effect, but what are you really seeing and what are you looking for?

Using a simple tool like a camera and flagging a tree and an individual leaf while photographing this same leaf on a weekly basis can allow you to see the increase or decrease in pests or diseases that help to make timely management decisions.

What you see is what you get, but a trained eye sees more. With perennial crops, some things change slowly including responses to water or fertilizer. In a drip or sprinkler-irrigated crop, what

happened when you increased water? This is difficult to assess if you increased water to the entire field. What if you increased the water on only half the field?

Now you have some idea of the impact of increased water, but then again not all places in the field are the same so there may be other variables at play, including temperature, and weather variables, including wind. For example, depth of plowing is never even throughout the entire field unless you're using artificial intelligence such as laser levelers and high-tech depth control of your implements.

Areas where only shallow plowing and tilling was performed compared to other parts of the field will affect water infiltration rates and may hold more water near the surface, affecting root growth, and can also result in uneven growth. A balance of water and oxygen is the key.

Too much water can cause anaerobic conditions (very low oxygen) around the roots, adversely affecting root growth which can lead to disease problems, such as Pythium and Phytophthora root rot or predispose roots to root-knot nematodes, especially in the second half of the plant life when little if any new roots are produced. Adversely affecting the roots and you affect the entire plant.

An important measure of good plant growth is uniformity. If plants planted at the same time are the same size, then you're doing something right; adequate and even irrigation, proper fertility, well prepared field or all of the above.

*Water & Roots*

Starting from the underground up, how does everything fit together? The challenge is that you see only half of the plant, the above ground part, so what do the roots look like and where are they at any given time in the growth of the crop?

Water keeps nutrients in solution and affects how rapidly plants will grow, but there's such a thing as growing too fast or stretching, which farmers worry about since it puts fruit out of reach faster than desired. Harvesting fruit from the ground without a harvest aid is generally twice as fast as harvesting fruit with a harvest aid or using ladders. The slower harvest rates increases labor costs to the point of diminishing returns with very tall trees.

*This is an extreme case of insufficient water. This is common in high clay soils, and can rip roots apart. Lahaina Series (Oxisol)*

Due to arid conditions in Ho'olehua especially during summer months,

papaya cannot be grown without irrigation, either drip or sprinkler or one of these at different stages of growth, starting with drip until plants are sexed then shifting to micro-sprinklers. What percentage of the roots are you irrigating? Are the roots you're watering carrying the load for the other roots or are the plants stressing out each day?

There are two types of farmers; those who apply too much water and those who don't apply enough. There may be a tendency to apply too much water if water is affordable and available, but how much is too much? When talking about water, you're talking about more than just the substance; it's about variables such as amount, placement, frequency, and duration.

Water also has a cooling effect and can influence the environment around the plant. It can modify the micro-climate and enhance the growth of disease, especially fungi and can also affect growth of pests such as insects and mites. How much water is required for your crop and how do you determine this? This is a moving target and changes with the seasons.

Extended hot dry summers can suck the water out of your soil around the plant to the point where you're running daily deficits even when applying what is thought to be adequate water. Digging around can help to locate where the water is. This is one way of knowing and there are others; with your finger? soil ball test? tensiometer? evaporation pan? historical data? All of the above?

Water is important but if you have little fertilizer in solution to optimize plant growth, then you're just spinning your wheels.

*Climate and Metabolic Rate*

Climate has a strong influence on how your papaya grows and its rate of growth; too slow and you may have difficulty keeping a market commitment or holding on to your market, while too fast and you run into all kinds of problems with nutritional deficiencies, fruit set, and fruit quality that manifests itself in the end product. What is good weather and bad weather?

*A high metabolic rate can manifest itself in many ways. Calcium is a mobile nutrient and many factors can influence its mobility including insufficient water, high temperatures, and high nitrogen.*

The metabolic rate of a plant is how fast it grows, and changes by season. Your personal metabolic rate changes from lazying in a lounger versus being chased by a raging bull. Changes in night and day temperature definitely affect metabolic rates. For you, having a

good night's rest is important so you're ready to attack the next day. Not having a good night's rest and you run the risk of internal breakdown from a cold or flu.

There are a lot of factors involved in human health and well-being such as rest, frame of mind and stress, exercise, and a balanced diet. Everything in moderation; understanding stressors is important not only for your well-being but also your plants.

Plants produce carbohydrates (sugars) during the day when these sugars move to the growing parts of the plant both during day and night. This redistribution of sugars from the more mature leaves is sent to the growing point to produce new leaves, flowers, fruit, and to the roots.

The distribution of newly synthesized sugars varies with stage of tree growth and whether the tree is flowering and fruiting. When papaya start to flower and set fruit, generally at the 40th to 50th node, root growth declines to nearly zero. This very low root growth creates problems if flooding occurs and root rot develops, so water management becomes very critical then.

Day and night temperatures have a strong bearing on sugar production and sugar distribution in the plant, plant growth and impact of other stresses such as water and nutrient growth and development.

Ideal papaya growing weather is not 95 degree days and 50 degree nights.

Humidity also has a strong influence on many levels, including metabolic rate, and while compounded by temperature can intensify impacts on the plant, pushing it over the edge and crashing the system. This situation can affect fruit set and increase skips; no flower, no fruits.

*If all goes well in the production system, a perfectly sweet papaya is produced for an ideal breakfast withcottage cheese and some apple banana and cereal with milk.*

Combined with overcast skies versus clear hot days, all of these are critical variables for plant growth. The faster the plant grows the more food and water is taken up and if you're not ready for this, bad things can happen to good farmers.

*"The severity of most diseases can be reduced and the chemical, biological, or genetic control of many plant pathogens enhanced by proper nutrition"*

*Soil and Nutrition*

In a highly weathered soil such as Oxisols, phosphorus can be tied up or 'fixed' in the soil colloid and unavailable to plants. Phosphorus availability can be pH dependent, meaning at a pH of

between 5.5 to 6.5, phosphorus can be released and available to the plant, while a lower pH will lock up phosphorus in the soil colloid.

Extreme cases of phosphorus fixation occur on Andesols found along the Hamakua coast where over 1800 pounds of 0-46-0 fertilizer is required to address phosphorus needs of crops, including overcoming fixation and having remaining phosphorus available to plants.

*Ho'olehua soils are Oxisols, well researched for pineapple production. This is the Lahaina Series*

The recommended rate of phosphorus application on Sunrise Papaya in Moloa'a, Kauai was 2 pounds of Treble Superphosphate fertilizer (0-46-0) in the planting hole at planting. Another 2 pounds of 10-30-10 fertilizer was applied at sexing. This seems like a lot of fertilizer, but there may be some special soil issues at play, such as fixation.

If this is the same soil as your organic farm in Hoolehua, to attain a level of 2 pounds of treble superphosphate or .92 pounds of $P^2 0^5$ per planting hole with organic fertilizer, it would require 12.5 pounds of 8-8-8 per planting hole! Based on a slew of soil samples in Hoolehua, calcium was shown to be the most consistently low nutrient, so this also needs to be addressed. Crop demands vary in their requirement for calcium and phosphorus.

This publication states, "On Kauai the soils used for papaya usually require liming and high levels of phosphorus fertilization." Find out more in this publication: http://www.extento.hawaii.edu/kbase/crop/crops/i_papa.htm

Nitrogen and phosphorus is only two of the many nutrients required for good plant growth, and are important in the early growth of papaya up to flowering and fruiting, then potassium becomes very important in producing fruits with high Brix. Managing nutrients starts at the pre-plant stage.

*Plant Selection*

Papaya can be very site specific in its adaptation, and plant and seed selection should be based on a cultivar's adaptation to your farm. Ho'olehua farmers are constantly selecting seeds from individual or groups of plants they believe are superior to the rest that meet their selection priorities, but this is a moving target. What are the most important priorities in plant selection? Total yield is important but grade-out is even more important. Having a plant adapted to your farm on a year-round

basis is the key. Here are some attributes to consider when selecting plants and fruits for seedling production:

1. Low bearing; first fruit low on the trunk (+/- 3 feet).
2. Least amount of 'skips'
3. Lack of carpellody or cat-faced fruit.
4. Consistent and attractive fruit shape.
5. Smooth glossy fruit.
6. Dark red-orange flesh.
7. Adequate fruit spacing on the column.
8. Slow rate of upward growth with good production. (Minimum stretching)
9. Long peduncle to accommodate more fruit per cluster.
10. Large trunk diameter
11. Large scavenging root system.
12. Fertilizer use efficiency
13. High fruit grade-out or least off-grade fruits
14. Tolerance to Powdery Mildew fungus.
15. Tolerance to Black Spot fungus.
16. Cold tolerance.
17. Heat tolerance.

All of these are important but which is the most important right now? Only the farmer can decide. Some characteristics will affect you now and some later, so the farmer needs to decide which plant or plants exemplify the total package. Taking seeds from another farmer might be a start, but not an end-all because your selection process will start all over.

*Control and Data Collection*

In farming, there are so many things you have no control over such as the intensity of the wind, temperature, and whether it will rain today, so you need to control the things you have control over and these things need to be fine-tuned and not left to guess work.

Keeping good records or even a journal will help to build on your knowledge base. When did the Black Spot occur last year, or when did I experience a lot of flower drop? Why did I experience skips or cat facing? Was it low nutrition or insufficient water or just high temperatures creating male sterility or low temperatures causing cat-facing?

*Black Spot Fungus is a major rainy season disease but can flare up in the dry season with Kona conditions resulting in high humidity and cool nights, and can adversely affect fruit quality and grade out*

If you're not improving on production each year, maybe you're doing something wrong or not doing something important. I doubt if farmers keep records of temperatures for the entire year or whether this will help to answer questions about problems

encountered but you should be aware of cause and effect.

Hot weather accelerates plant growth to the point where nutritional shortages become apparent and manifests itself in the end product. It starts with the lack of water, and some if not all nutrients cannot move through the plant especially to the tips.

And what is at the tips? Fruit and the main growing tip. Since plants are growing at phenomenal rates, it results in misshapen, stressed fruit with poor shelf life and poor eating quality. This can be caused by a combination of factors that have to be sifted through to find the root cause.

High temperatures affect pollination and flower parts ability to function. It can cause flower abortion, shift in the sex of flowers to male, and misshapen, unmarketable fruit. Cold weather can also affect the flower's ability to create a good marketable fruit by shifting the male parts of the flower to fuse with the female parts to create cat-faced fruit.

Selecting plants that can overcome these conditions is only half of the equation. You will need to select from the same lines those that have cold tolerance with less carpeloidy or cat-facing present is important. Nutrition also has a role on how these issues manifest itself so you will want to get the nutritional factor out of the way early to eliminate this variable.

*Water & Temperature*

Understanding how stress manifests itself on papaya is a good place to start. Understanding temperature, both air and soil and its impact on plant growth, or sufficient or insufficient water for optimal growth is important.

Last summer, very hot days resulted in pan evaporation rates that hit 1 acre inch of water in two days! Extrapolating, this is equivalent to 3.5 acre inches or 95,039 gallons of water per acre per week!! This is a reality as we head into the new normal.

*Plastic mulch helps to control weeds, but can increase soil temperature. Temperature beneath the mulch can exceed 130 degrees F and increase metabolic rates to the point of crashing the system.*

How do you remedy the situation? Organic mulch, plastic mulch, cover crops? Plastic mulch can increase soil surface temperatures so they exceed 130 degrees F! What is the effect of the plant under these conditions? It will definitely increase the plant's metabolic rates.

There are so many moving parts that if you only look at one thing, you might be missing the more vital points. The

growing environment not only involves plant and soil but also air temperature and humidity which are influenced by the wind direction and intensity.

The cooling effect of wind can also affect humidity levels and the micro-environment around the plant. Kona wind conditions and summer temperatures can reach the mid-90's with 90% humidity and again, flower pollination and flower set will be adversely affected.

How can you prepare for these kinds of conditions? Some ways include how you orient your fields to the wind, plant spacing including in-row and between-row spacing, and the amount and spacing of windbreaks if you're in a windy area.

*Creating Conditions for Disease*

Temperature and humidity also affect conditions conducive to diseases such as Powdery Mildew, an ongoing disease challenge for Ho'olehua papaya growers. This disease is around for a larger part of the year than Black Spot.

In a recent vegetable magazine survey, powdery mildew was identified as the most serious vegetable crop disease across the U.S., probably due to the fact that so many crops are affected. However, there are many powdery mildew genera and species specific to crops and crop families.

Powdery mildew attacks both leaves and fruits, and limits photosynthesis affecting fruit quality, quantity, and production. Like powdery mildew, some diseases are very specific in their climatic requirements and may attack in certain seasons when the temperature and humidity are ideal for proliferation of this disease.

A publication on Powdery Mildew of Papaya will help to better understand this disease:

https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-90.pdf

*White powdery spots of Powdery Mildew, powdery patches of spores, and also mycelia that penetrate leaves to seek nutrients causing premature leaf drop.*

Climate change is defined as extreme weather that can manifest itself in the form of shifting high and low temperatures, and severe weather episodes such as torrential rains and strong winds. It can also mean unseasonable weather such as hot winters and torrential rains during summer months.

A good example of the effects of climate change are recent outbreaks of Black Spot on Molokai brought on by the lack of trade wind weather resulting in wet mornings creating ideal conditions for

this fungus to proliferate. This allowed the inoculum to maintain high levels instead of being suppressed from extended dry or windy weather.

A normal spring would include moderate trade winds that have a drying effect on fields, even after a rain, and is not conducive to the spread of Black Spot. Knowledge is power. Controlling disease outbreaks starts by understanding the disease and how each variable affects the disease.

Here is a publication addressing Black Spot on Papaya:

https://gms.ctahr.hawaii.edu/gs/handler/getmedia.ashx?moid=65912&dt=3&g=12

*Anthracnose fungus can still be a major post-harvest problem affecting shelf life and appearance on the store shelf. Plant health also plays a role in warding off this fungus.*

Anthracnose fungus of papaya used to be one of the most important post-harvest diseases and seems to be taking a back seat to Black Spot Fungus lately. Proper plant health can minimize this disease. If plants are under stress, either nutritional, weather related or both, this disease can be more prevalent. The papaya skin can be armor against surface invasion if it's thick and healthy.

Here's a publication on Anthracnose fungus:
https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-103.pdf

Although you may not be able to anticipate when these challenges will occur, you should have some tools in your back pocket, and at least have a strategy to deal with some of these challenges. Be ready to make adjustments to your production system if necessary.

In an organic system, you are left with fewer tools and quick fixes at your disposal compared to conventional systems, so holistic strategies start by growing a healthy plant, along with cultural controls such as tight monitoring of irrigation, possibly irrigating early in the day so the plant environment is dry when the sun goes down. Another is keeping the disease population, including inoculum low by picking off diseased leaves when plants are young.

Sulfur is a common catch-all for mites, powdery mildew, and probably other pests. It creates micro-doses of Sulfuric Acid to fry both diseases and pests. But it also affects the pH of the environment. Copper compounds have been used for Black Spot but which one is the best and can they be used in combination with sulfur?

For every yin, there's a yang. What are the downsides to everything you do? Copper is also a heavy metal that's essential for plant growth in miniscule amounts, but it can be an environmental pollutant.

*Plant Density and Orientation*

There's a natural tendency to pack plants in because you're focusing on yield; the more plants per acre, the higher the yield. Is this really true? It depends on whether you want a lot of mediocre fruit or the best that you can produce.

Plant density also affects fruit size so looking at what the market wants is important in plant spacing, but there are many other variables such as water and amount of fertilizer, probably others. It may come to the point of diminishing returns if your 'plants per acre' are too high and you're not meeting market preferences.

Close plant spacing creates competition between trees for water and nutrients, and their roots may be entwined so essentially they're competing with each other for survival. High density plantings affect air flow through the fields, creating an ideal environment for an explosion of mites. Compounded by plant stress, a double whammy can take an orchard down earlier than anticipated.

At one time, one of the Moloa'a, Kauai papaya farmer's priorities were the selection of plants with shorter branches so they could plant them closer in rows, again following the thinking that more plants per row will result in a higher yield.

*What is the ideal plant spacing? Should rows run north to south or eat to west to improve air circulation? Freeman Farm, Ho'olehua*

There were also cost savings since less irrigation was required for the number of trees planted per acre. But one thing you don't want to happen is having leaves between trees overlapping, increasing competition and limiting photosynthesis. Having leaves between plants meeting tip to tip is the ideal spacing.

How are your rows oriented in relation to the path of the sun? During winter months, the sun will follow a more southerly path and will not travel directly overhead. How does this affect your plants ability to capture sunlight and optimize photosynthesis?

*Soil*

Everything starts with soil and maybe it should be at the front of this newsletter. Soil type is also an important consideration. We have about 140 soil types and some are great for papaya

while others are not. Ideally, well-drained soil is better than high clay soil. Different soil types are connected to different weather regimes, and can have a strong influence on soil quality and nutritional status.

Wetting patterns differ with different soils as well as inherent soil nutrient status. Some have a tendency to tie up elements if the pH is not adjusted properly. We have most of the climatic zones in Hawaii, and when you put soil types and climate together, there are over 1000 microclimates in Hawaii and papaya will respond differently in each microclimate.

Knowing the nutritional status of your soil is an important first step in determining what is there and what is required for ideal growth. Farming without a soil sample is like trying to cook a difficult dish without a recipe. You might succeed or you might flop.

Don't assume that you know the nutritional status of your soil. This starts but reviewing soil survey maps to identify your soil series first, then collecting a soil sample and submitting it with the name of the soil series. This is critical because some Hawaii soils have unique characteristics that require special management.

The area of soil building, management and nutrition could take an entire newsletter. As a start, here's an excellent webinar on 'Ecological Nutrient Management for Organic Production in the Western Region':

https://youtu.be/hkXBexLSefk?t=4628

Only a few papaya growing areas have soil similar to ours, and the closest would be Moloa'a on Kauai that also has red, high iron soil. But they're on the east coast along the shore and not in the central plains, so this is definitely a research project.

Well drained soil is the ideal so you don't have standing water which results in disease and nutritional issues, but how you management and build soil plays a role.

> *"If you follow practices that build and maintain good levels of soil organic matter, you will find it easier to grow healthy and high yielding crops. By maintaining adequate levels of organic matter, you have less reason to use as much commercial fertilizer, lime, and pesticides as many farmers now purchase. Soil organic matter is that important."*
>
> *Building Soils for Better Crops*

*Organic Matter Production*

Tied to good soil practices and soil building is organic matter production. Oxisols are highly weathered and have little organic matter and this is critical to long-term sustainable crop production. Practices such as cover cropping, green manures, and importing organic matter help to increase organic matter in soils which can have a positive impact not only by improving the microbiological environment for microbes to thrive and feed the soil system, but also to

increase the water holding capacity of your soil. With water shortages in many farm production areas, increased water-holding capacity is an often overlooked benefit.

Setting long-term targets to build soil organic matter is a good start. A target of 5% organic matter will equate to 100,000 pounds per acre, assuming 2 million pounds in an acre-foot of soil. This is not something accomplished in a season or even in a few years; this is a long-term goal that only those with a long-term lease on farm land can realize but is a worthy goal to work toward.

The selection of cover or manure crops should take into consideration what you're trying to accomplish in growing these crops. Is it to break a disease or pest cycle such as root-knot nematodes and southern blight or increase soil nitrogen, decrease water use or is it just to increase organic matter? Cover and manure crops should be an important part of a long-term crop rotation to address more than one goal.

In Oxisols where organic matter content is low, cover crops play an important role in building organic matter but many other benefits need to be measured. Here's a new USDA SARE report on cover crops answering the question, "When Do Cover Crops Pay?"

https://www.sare.org/Newsroom/Press-Releases/When-Do-Cover-Crops-Pay-New-USDA-SARE-Report-Addresses-the-Question

Sunn Hemp is an excellent green manure and also suppresses root-knot nematodes. 'Tropic Sun' Sunn Hemp was developed at the USDA Natural Resources Conservation Service Plant Materials Center here on Molokai.

*Bean Common Mosaic Virus on a Crotalaria species found on the Big Island. Photo credit: Mike Melzer*

However, two viruses have recently been found infecting a Sunn Hemp seed crop on Molokai, and another virus was found infecting wild crotalaria on the Big Island. Although these diseases are not spread through seed, it will hamper seed production efforts in many areas of the state since it affects the amount of seed produced.

Aside from its properties of nitrogen and biomass production, as well as root-knot nematode suppression, this variety was also selected for its very low toxicity affecting livestock since many crotalaria varieties are toxic to livestock. The selection of 'Tropic Sun' Sunn Hemp involved releasing cattle into a variety trial and observing which cultivars were consumed the most.

Sorghum-sudan hybrid grasses also have many positive attributes as a cover crop. Aside from heavy organic matter production and nematode suppression, scavenging root systems reach deep into the soil to bring up nutrients lost by leaching.

Although they require nitrogen fertilizer for good growth, payback comes with valuable organic matter, relieving compaction, and smothering and suppressing weeds. Timing plantings to coincide with winter rains can save on irrigation. Selecting sterile seed varieties or long day types will prevent fields from going to seed and becoming a weed on Hawaii farms.

Here's an excellent publication on sorghum-sudan grass as a cover crop:

https://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Nonlegume-Cover-Crops/Sorghum-Sudangrass

*Strategy/Approach*

Like farming, you can start from the beginning or you can start with the end in mind, or both. Looking at it from both ends is a little more complicated but when you start determines when you end, or when you deliver the first fruits to the market, as well as how long you can deliver to the market from the same tree.

Everything is connected and it's very difficult to look at one thing independent of everything else. Spacing is related to the amount of water required, the frequency of irrigation, and the amount of nutrients required to grow a healthy crop.

*Putting it Together*

Yield is important but what is more important is matching your 'papaya tree' to the conditions you're dealt with. And by the way, it's not a tree; it's an herbaceous plant with a hollow stem. Papaya is a tropical species that prefers tropical weather. However, Hawaii is on the fringe of the tropics and considered sub-tropical, and this probably means we have colder weather than in the tropics, and this becomes a liability and not a benefit for papaya producers.

*Weather Extremes*

During winter months papaya growth is greatly reduced and I hear farmers complaining that "my plants are just sitting there and not growing!" The growth rate declines from 2 to 2.5 leaves per week to sometimes less than 1 if temperatures are below 55 to 60 degrees F.

Fruit development is also delayed from 150 to 164 days by 14 to 21 days. In cooler subtropical climates, papaya can take up to 250 days to mature. This is common for many tropical species that include banana, taro, and sweet potato. Time to harvest for Brazilian banana can change from 90 days from flowering to harvest for late summer harvest to 140 days for autumn flowering.

The effects of cold winters in alfalfa production on Molokai is evident when plant stems turn purple from low phosphorus uptake, but based on soil samples, P is adequate. So what is this caused by? When the soil becomes cold, phosphorus uptake is inhibited. The only way to deal with this is how you deal with many other problems in farming; anticipating this weather and preparing for it.

A simple way to start is by understanding day length and temperatures on at least an annual basis, and its impact on plant growth. The temperature curve is following the day length and growth curve although there's a cumulative effect on temperature that can last until September even though the longest day is June 21. It's like heating up a pot and seeing how long it can stay hot after you heated it.

Armed with this information, it's fairly easy to predict when this problem is going to occur so you can prepare for them. The question is what problem are you going to deal with first? Insect growth cycles speed up with increasing temperature and day length.

Preparing for weather changes means getting your plants ready for less than ideal weather by making sure your nutritional program is running on all cylinders in order to help sail through bad weather. But too much is just as bad at not enough?

*Hermaphroditic fruit has a characteristic light bulb shape and is the only type of papaya you can sell in the fresh fruit market in Hawaii.* ▪

In a desert, water placement and frequency is important. You can estimate water needs through records of evapotranspiration rates in your area as a starting point or using a tensiometer or by digging around to see where the water is and how much.

Water placement is very important in irrigating the roots at different growth stages. Where are your roots? This is a moving target and you may have to adjust your irrigation system to the different growth stages. Do you utilize 2-3 lines of t-tape or poly pipe with emitters attached or micro-sprinklers, or poly pipes with built in emitters? Cost is also an important factor.

Each has its pros and cons and can also affect the amount of weeds you have to contend with. Weeds can be your biggest challenge on a long-term crop like papaya. Utilizing plastic mulch can help in the in the first half of production, but will start to deteriorate.

The amount of water and frequency of irrigation is important. There are some

who believe that you want to keep the moisture level consistent, while others believe you want to mix things up and allow plants to dry between watering to break disease cycles that require constant moisture. I would go with the latter.

Too much water especially near the base or crown, and you create conditions conducive to diseases such as Pythium, which loves warm, wet conditions or root-knot nematodes which love weak plants.

*There are many ways to irrigate a crop, and it can change through the life of the crop. At planting, banana can be irrigated with emitters then converted to micro-sprinklers between mats when plants fill the hole. The same strategy can be used for papaya where converting from drip to micro-sprinklers can occur after sexing.*

The use of micro-sprinklers between trees in the row is common on Molokai, water reaching the base and trunk of trees on both sides of the micro-sprinkler can create ideal conditions for Pythium if plants are overwatered or allowed to stay wet between watering.

Overwatering may elongate plants, putting out of reach of easy harvesting sooner than anticipated, decreasing total yields. I don't know if I'm helping things here; only bringing you to a realization of what you have to be aware of. Knowing how to grow it is one thing, understanding why things happen is another, and how to fix it takes in account at least the first two.

This is the art and science of agriculture and you need knowledge of both. If you don't understand the science, you'll have a difficult time troubleshooting. Knowing how to plant, maybe fertilize, and keep them alive isn't good enough; you need to understand cause and effect and the science behind it. Knowing how to use the science is what the 'art' part is about.

Considering all your efforts in growing and nurturing the crops this can be undone by poor harvesting and handling practices. The major problem is mechanical injury both from abrasion and impact injuries. Papaya is easily damaged by wind, and though not very obvious during harvesting or packing, they are plainly visible as the fruit ripens.

For more information on papaya post-harvest quality maintenance guidelines, please review this publication:

file:///C:/Users/Jen/AppData/Local/Microsoft/Windows/INetCache/Content.Outlook/OQ816437/Papaya%20Postharvest%20F_N-34.pdf.

You might want to consider how you interact with your plants drawing on some human analogy. Is it a love-hate relationship or one built on trust with a long term commitment? Or are you always playing catch-up? Or is it 'see you when I have the time?' or 'I'm available for you anytime.' Like any relationship, what you put in is what you get out, but it needs to be quality time talking things through and digging deep to understand.

Walking the field every day is the ideal but not always the most efficient or effective way to use your limited time. Acting on changes puts the walking into action, instead of walking the field and not really being there. You're looking for minute changes and determining what this all means.

*Ho'olehua organic papaya production. Photo credits: Tania & William 'Junior' Kaholoa'a*

There are many things on the farm that have to be taken care of, but there are many things off the farm that have a strong bearing on your success on the farm, and identifying all of these are very important. If you're not aware of them, your papaya world could be smaller than it should be.

This exercise is not intended to provide a lot of solid answers, but hopefully it will get you to the realization that everything in your production system is connected and to envision all the pieces of the puzzle and how they fit together.

Long term crops such as papaya take a lot of advanced planning because many times when you encounter a problem, it may have to do with something that occurred months or weeks earlier. A good farmer can see all the pieces, but it still comes down to controlling the things you have control over. This is not rocket science but sometimes it seems like it is.

***Acknowledgement**: Special thanks to Dr. Robert Paull for his critical review of this newsletter.*

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*Well, we just passed the halfway mark for the year, and this is actually the Spring Edition, but catching up soon. Farming will get more difficult with climate disruption, including global warming and sea level rise, and farmers have to be on the cusp readjusting their production system to these challenging times. The only time we'll take action with sea level rise is when the water is at our ankles then we'll need some friends or family in high places. Next time…*

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