Tomato Breeding in Hawaii

by Glenn I. Teves, County Extension Agent
University of Hawaii College of Tropical Agriculture and Human Resources
Cooperative Extension Service - Molokai

The book on Tomato Breeding in Hawaii has never been written, and most of the people who were involved in this special work are long gone, but research reports provide snapshots of some of the challenges these bold individuals confronted, and the successes they achieved. UH tomato breeders created a legacy that impacts tomato production even today.

Fluted tomatoes found in Mexico, including Oaxaca.

The purpose of this newsletter is to highlight the basic and applied tomato research at the University of Hawaii College of Tropical Agriculture and Human Resources over the last 75 years that fed into a national system of tomato research focused on the development of disease-resistant varieties that continue to be the back-bone of tomato breeding programs globally. With a year-round growing climate, Hawaii breeders had the potential to accelerate tomato crop improvement 2-3 times faster than in other parts of the U.S.

Tomato production is probably more important now than in the past due to increased consumption by many cultures and the diversity of products created, beyond simply the fresh tomato. Although not the most nutritious vegetable, the scale on which tomato is grown globally makes it one of the most important vegetable crops.

A member of the Solanaceae family or ‘sun lovers’ along with peppers, eggplant, and irish potato, tomatoes originate in a region of Central and South America, from Mexico to Chile, and are adapted to a wide range of environmental conditions, from dry to wet, and from upper elevations to harsh shorelines with salt spray. Genes for fruit color span a wide range including blue, brown, red, orange, yellow, and green, and also include color combinations with stripes and two-tones.

An Earth Day 2016 exhibit of tomatoes grown on Molokai, including the UH variety Kalohi, named after the channel between Lanai and Molokai.

This broad adaptability and disease resistance traits provide a diverse gene pool

that few other vegetable species can match, and allows tomato breeders the flexibility to select from a palate of genes to create the tomato of tomorrow. Some of the novel varieties are highlighted in pictures throughout this newsletter.

Genes derived from wild species L. esculentum, L. chilense and L. cheesemanii were used to create blue tomatoes. Black Sand Beach created by tomato breeder Gary Cass.

The Latin name of the tomato has recently changed from *Lycopersicon esculentum* to *Solanum lycopersicum*. However, to minimize confusion, the old names are used throughout this newsletter.

Wild *Lycopersicon* species provide the germplasm to improve the cultivated tomato including jointlessness and salt-tolerance from *L. cheesmaniae*, resistance to Botrytis mold, Septoria leafspot and pest resistance from *L. hirsutum*, resistance to curly top virus from *L. chilense*, resistance to Fusarium Wilt, Stemphylium gray leafspot, *Cladosporium* or *Fulvia* leaf mold, and spotted wilt virus from *L. pimpinellifolium*, and resistance to Anthracnose, Alternaria collar rot, and Verticillium wilt *from L. esculentum var. cerasiforme*, the wild cherry tomato found on waysides in Hawaii. More of these resistant traits continue to be fleshed out through basic research.

A major challenge in utilizing wild species is that bad traits are brought into the mix such as small fruit, fruit cracking, poor fruit shape or cat-facing, puffiness, uneven ripening, soft fruit or enzymatic breakdown, and bad taste. Unravelling these linkages and adjacent bad genes requires more work through field selection to separate desirable from undesirable traits.

Tomato breeding is a moving target with unique regional problems. A myriad of tomato diseases exist in every corner of the world, let alone the U.S. and Hawaii, from Tomato Spotted Wilt Virus (TSWV) to Tomato Late Blight to Tobacco Mosaic Virus (TMV), *Alternaria* and *Septoria* leaf spot, Bacterial Wilt and Bacterial Speck, just to name a few.

Tzi Bi U, a Chinese striped tomato also known as Violet Jasper surrounded by Juliet, a very popular mini-roma from Taiwan.

But this is a long, hard road through conventional methods of Mendelian genetics which has morphed into manipulation through genetic modification. But basic research is still the most important tool in moving the work along because in the words of computer geeks, ‘garbage in, garbage out.’ Without great tomato stocks to start with, you cannot move forward and this

applies to all forms of vegetable genetic work.

Blossom End Rot is a physiological condition caused by a combination of factors, including environmental, genetic, nutritional, and also water management. Selection of tolerant varieties is important to minimize this condition.

Large-fruited tomatoes lack a disease-resistance package required to survive the mood swings in Hawaii weather, from torrential rains to hot, humid lowland conditions with a small day/night temperature differential. Many varieties cannot adjust to these diverse climatic conditions, and will succumb to stress followed by whatever malady is in the environment.

Selecting for large-fruited tomatoes also moves you away from disease resistance found mostly in wild, small-fruited varieties. So was the challenge for tomato breeders in Hawaii, how to incorporate resistance to diseases of the day in a large-fruited tomato.

This wasn't easy because the small-fruited characteristic was a dominant trait and in most situations when crossing a large-fruited variety with a small one, the resulting progeny pulled closer to the smaller parent. This was a long journey, and many breeders gave up or just settled on a tomato that could survive.

Changing weather and new diseases along the way influenced the plant improvement programs, and the need to change priorities and direction. Also, in all good breeding plans, assessing the lay of the land is an important starting point. What diseases are creating the biggest problems for Hawaii farmers?

A new tomato variety released to farmers had to be a marked improvement in all aspects over the farmer's existing variety or it wouldn't be adopted. It doesn't make sense to grow a new tomato variety with resistance to just one disease when farmers still needed to spray for three other diseases, and this has been documented in research into farmer's adoption of a new tomato variety.

Indeterminate tomatoes pruned and grown on a trellis on Molokai.

Blondkopfchen or Blond Girl, a floriferous heirloom from Germany produces sweet yellow teardrop shaped fruits.

A new variety, in order to be adopted by farmers, has to be as rugged as their existing variety with a comparable shelf life, as red as the last one, with red gel, and no deficiencies. It also had to be of comparable size and shape of the existing variety, and this was a difficult package to create.

The new tomato selection also had to taste good or better than the farmer's variety. A very subjective topic that can be argued by many, what does a great tomato taste like? It's probably a balance between sweet and sour and a pleasant aftertaste, not bitter or astringent. Some of the wild disease-resistant varieties contain high levels of alkaloids such as tomatine and solanine that gave the new tomato selection a really bad taste, and had to be selected out when incorporating disease resistance into a commercially acceptable tomato.

The story of tomato in Hawaii starts after the arrival of Captain James Cook and other early explorers in the late 1700's or early 1800's. Records of tomato breeding at the University of Hawaii started around the late 1930's. Tomato breeding required a strong focus on priorities with a team of people, not just one individual, to take on this monumental task. In the tropics, diseases never disappear; they just reappear when the conditions are right. Where to start in tomato improvement is the real question. Foliar diseases seemed to have been a focus along with the dreaded Tomato Spotted Wilt Virus (TSWV), a disease Hawaii farmers still deal with today.

An early UH publication dealt with tomato diseases and how to control them by chemical means, including Gray Leaf Spot *Stemphylium solani*, Early Blight *Alternaria solani,* Late Blight *Phytophthora infestans*, and Septoria Leaf Spot *Septoria lycopersici*.

The 1930's were difficult times as America was in the grip of a crippling depression, and job creation by then-President Franklin Delano Roosevelt focused on sending men into the hills to plant trees as part of the Civilian Conservation Corps. World War II, starting with the Pearl Harbor attack of December 7, 1941 changed the direction of the nation, and put everyone to work, breaking the longest, deepest, and most widespread depression of the 20th century.

A dark-blue Shadow Boxing, a variety developed by Tom Wagner of Everett, Washington that turns red with orange stripes when ripe.

During the war, Hawaii produced approximately 5,300 tons of tomato annually

valued at $1,286,000, destined for the local wholesale market and the armed forces. Everyone was encouraged to grow a garden since Hawaii could easily be cut off from food supplies on the West Coast. The Victory Garden was a symbol of the community's support for the war, and also maintaining food production for our nation at war. At that time, Hawaii was much more food self-sufficient than it is today.

Janis Joplin, a medium-sized green and yellow striped tomato with good taste developed by Gary Cass.

The Hawaii tomato breeding program included K. Kikuta, W.A. 'Tex' Frazier. J.W. Hendrix, D.C. McGuire, J.F. McFarlane, C. F. Poole, R.K. Dennett, J. C. Gilbert, J.C. Acosta, and a host of others, including research assistants and students. The UH team evolved as new breeders built on the successes of the past.

Tomato Spotted Wilt Virus (TSWV) was identified as the most pressing disease on tomatoes in Hawaii with production losses of 30-50%. The tomato variety popular in Hawaii at that time was 'Bounty', an early determinate tomato that produced good yields in Hawaii but was very susceptible to TSWV.

A tomato selection from M.W. Gardner of California Agricultural Experiment Station, BC-10, a *L. pimpinellifolium* derivative was highly resistant to TSWV in Hawaii but unfruitful in observation trials here. Crosses between Bounty and BC-10, with selections made through 8 generations resulted in the development of Pearl Harbor, a heavy-setting, high-yielding variety with resistance to the Hawaii strain of TSWV.

Pearl Harbor had less than a 1% infection rate in field trials with yields exceeding 24 tons per acre. The resistance was dominant and could easily be transferred to other varieties. However, the fruit was smaller than Bounty and it was recommended that Pearl Harbor be planted only where TSWV was a serious problem.

Partnerships with other universities enabled UH breeders to create a superior disease-resistant tomato to address the production issues of its day, and this model was beginning to bear fruit. However, breeders couldn't rest on the laurels of yesterday because new diseases were beckoning, and solving one production problem just moved a host of other disease and pest problems further up the list of breeding priorities.

'Black & Blue' created by Gary Cass. With good exposure to the sun, it will turn almost totally blue.

Hawaii breeders embarked on a major breeding program to find resistance to the

main tomato diseases in Hawaii by crossing a handful of commercial varieties with wild disease-resistant species. Commercial varieties included German Sugar, Bounty, Pritchard, Pan-American, Rutgers, and Home Garden. Some of these varieties also contained wild species other than *L. esculentum*, such as *L. hirsutum*. It was also determined through later field trials that German Sugar was also resistant to TSWV.

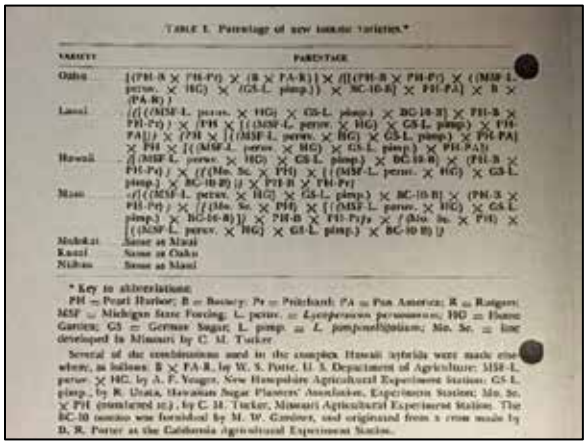


TABLE 1. Parentage of new tomato varieties.*

VARIETY	PARENTAGE
Oahu	[(PH-S × PH-Pr) × (S × PA-R)] × {[(PH-S × PH-Pr) × ((MSF-L. perus. × HG) × (GS-L. pimp.))] × BC-10-S} × PH-PA] × S × (PA-R) }
Lanai	{[((MSF-L. perus. × HG) × GS-L. pimp.) × BC-10-S] × PH-S × PH-Pr) } × {PH × [((MSF-L. perus. × HG) × GS-L. pimp.) × PH-PA]} × PH × [((MSF-L. perus. × HG) × GS-L. pimp.) × PH-PA] × PH × [((MSF-L. perus. × HG) × GS-L. pimp.) × PH-PA]}
Hawaii	{[(MSF-L. perus. × HG) × GS-L. pimp.) × BC-10-S] × (PH-S × PH-Pr) } × {(Mo. Sc. × PH) × [((MSF-L. perus. × HG) × GS-L. pimp.) × BC-10-S]} × PH-S × PH-Pr}
Maui	{{[((MSF-L. perus. × HG) × GS-L. pimp.) × BC-10-S] × (PH-S × PH-Pr) } × {{(Mo. Sc. × PH) × [((MSF-L. perus. × HG) × GS-L. pimp.) × BC-10-S]} × PH-S × PH-Pr}} × {(Mo. Sc. × PH) × [((MSF-L. perus. × HG) × GS-L. pimp.) × BC-10-S]}
Molokai	Same as Maui
Kauai	Same as Oahu
Niihau	Same as Maui

* Key to abbreviations:
PH = Pearl Harbor; S = Bounty; Pr = Pritchard; PA = Pan America; R = Rutgers; MSF = Michigan State Forcing; L. perus. = *Lycopersicon peruvianum*; HG = Home Garden; GS = German Sugar; L. pimp. = *L. pimpinellifolium*; Mo. Sc. = line developed in Missouri by C. M. Tucker.

Several of the combinations used in the complex Hawaii hybrids were made elsewhere, as follows: S × PA-R, by W. S. Porte, U. S. Department of Agriculture; MSF-L. perus. × HG, by A. F. Yeager, New Hampshire Agricultural Experiment Station; GS-L. pimp., by R. Urata, Hawaiian Sugar Planters' Association, Experiment Station; Mo. Sc. × PH (unnamed as), by C. M. Tucker, Missouri Agricultural Experiment Station. The BC-10 used was furnished by M. W. Gardner, and originated from a cross made by S. R. Porter at the California Agricultural Experiment Station.

Complex crosses to create the seven island varieties included popular varieties of the day along with wild tomato species to incorporate multiple disease resistance.

Wild species included *L. pimpinellifolium*, and also an unusual cross between Michigan State Forcing and *L. peruvianum*. A wild variety, *L. peruvianum* is resistant to Root-knot Nematodes but in conventional breeding with *Lycopersicon esculentum*, is incompatible. In 1944, a major breakthrough by P.G. Smith of U.C. Davis combined *L. esculentum* 'Michigan State Forcing' with *L. peruvianum* P.I. 128657 through embryo culture. This innovation allowed disease-resistant traits from *L. peruvianum* to be transferred to commercial tomato varieties through conventional breeding methods.

The seven tomato varieties were named after the major islands, Maui, Lanai, Oahu, Molokai, Hawaii, Kauai, and Niihau.

Although originally selected for resistance to Spotted Wilt Virus, *Stemphylium* grey leaf spot, and *Fusarium* wilt, some of the island selections were later determined to have resistance to other diseases. Resistance to Root-knot Nematodes and TMV from *L. peruvianum* would be fleshed out in later field trials.

Root-knot Nematodes, microscopic eelworms, burrowed into tomato roots created galls and impeded the flow of nutrients and water causing stunting and early death of plants, and was a major pest of tomato and other vegetables, especially in the tropics.

Some of the island series, including Molokai and Lanai and a cross between the two, Kalohi, also exhibited tolerance to damage from Spider Mites, and this physical resistance was the result of increased hairiness from trichome hairs, varying lengths of hairs to prevent insects from reaching plant parts, probably from a wild parent, *L. hirsutum*, the hairy tomato.

Swelling of root tips caused by Root-knot Nematodes, including Meloidegyne incognita and M. javanica are major pests on vegetable crops, including tomato. This is M. javanica on taro.

The 1940's was a time of accelerated research in tomatoes nationwide. On the cusp of a new revolution in tomato breeding,

a coordinated regional tomato breeding program was taking hold. Through partnerships between USDA and land-grant universities of the southern and western U.S. including Hawaii, the Southern Tomato Exchange Program or STEP was created.

Heavy fruit setting on the determinate yellow grape tomato, Aria.

C.F. Andrus of USDA championed the STEP initiative and engaged key tomato breeders, many of whom had backgrounds in genetics and plant pathology, a key combination of expertise to take on this important task. The purpose of this program was to improve regional tomato production through the sharing of germplasm.

Field trials were conducted in over 40 agricultural experiment stations at participating universities, and included tomato selections from each state. Each university focused research efforts on disease issues of their region, and this coordinated effort also allowed tomato breeders to see how their selections fared in other conditions across the nation, especially in the south and southeast where climatic conditions were ideal for many tomato diseases. Each entry was given a STEP number, such as STEP 390, to remove bias in field evaluations. The best tomato selections in each trial were utilized for crop improvement by cooperators across the south and Hawaii, and released to growers.

J.C. Gilbert had a background in Plant Pathology and Genetics, an ideal combination of skills to continue the work on disease-resistant vegetable varieties, including tomato. A former instructor at Kamehameha School for Boys, he carried the work forward by incorporating additional disease resistance into Hawaii tomato lines.

One of the challenges of incorporating root-knot nematode resistance into a commercially acceptable tomato was deficient or ‘bad’ genes in proximity or linked to the Mi gene conferring root-knot nematode resistance. These traits were especially inherent in some of the wild species.

Extreme cracking from heavy rains on the tomato variety ‘Black Sand Beach’

They included susceptibility to fruit cracking, including radial, concentric, and combination cracking, cat-facing or fasciated fruit, puffiness, and soft fruits believed to be caused by enzymatic

breakdown, and it would take several generations of selecting to cull out the bad traits. Some of the bad traits were also caused by a combination of environmental effects and genetic anomalies.

Jim Gilbert visiting a bean field in Seabrook, Maryland with Dr. Gil.

Jim Gilbert, with a team of able students and assistants, also focused on improving resistance to TMV found in *L. peruvianum*. Since resistance to TMV was a recessive trait, additional effort was required to maintain resistance in tomato lines, and to assure that in a hybrid, both parents possess TMV resistance. Saving seeds from previous generations didn't assure TMV resistance would be transferred to future generations, and dominant genes were easier to work with in transferring resistance to the next generation.

To further magnify TMV resistance, more than one source of resistance was sought after. Jim Gilbert focused on 'stacking' resistant genes, identifying resistant genes from more than one source to bolster resistance and this gave additional insurance that resistance would hold up better over generations. TMV can also be transmitted from infected seed which makes it a greater threat. Tobacco is also a member of the Solanaceae family, and TMV can be spread through cigarette smoke that imbeds the virus on clothes and hands.

Hawaii breeders also worked to increase the nutrient content in tomato especially Vitamin C. Charles Poole retired from USDA and moved to Hawaii to work on vegetable breeding at UH, and won a national award for this effort.

Some universities focused on developing open-pollinated varieties, while Hawaii breeders opted for the development of both hybrids and open pollinated selections for release to growers. Other universities also got involved and benefitted from this research, including Ohio and Michigan whose growers faced major bacterial disease challenges. Hawaii focused on multiple disease resistance, especially root-knot nematodes and tobacco mosaic virus, and also foliar diseases.

Jack Tanaka played an important role in vegetable breeding at UH and also oversaw the sweet potato and eggplant breeding program.

Areas such as Florida focused on resistance to Bacterial Wilt *Ralstonia solanacearum*, a serious soil-borne disease, resistance to new strains of Fusarium wilt, and tolerance to high temperatures, while other states such as South Carolina focused in increasing fruit quality characteristics in addition to Bacterial Wilt. Access to

germplasm with new resistances enabled breeders to not only focus on disease resistance but also taste, fruit size, and appearance.

Grape tomatoes are the craze because they have a good shelf life, are the right size for plunking in your mouth, and don't require slicing. Sugary (red) and Aria (yellow) are two excellent varieties from Taiwan.

By utilizing one of the island varieties, Molokai, and through further crossing, he developed the important variety Anahu in the 1955's, the first commercial variety to combine resistance to Spotted Wilt, Gray Leaf Spot, Fusarium Wilt and Root-Knot Nematodes. Anahu was also a source of Spider Mite resistance utilized by the USDA to develop large-fruited processing tomatoes. This was a major contribution to the national effort in developing multiple disease resistance in a commercial tomato, especially Root-knot Nematode resistance.

Anahu won major accolades in trials throughout the southern states and was the basis for incorporating nematode resistance. Today, many commercial nematode-resistant tomato varieties can trace their genealogy back to Anahu, including Celebrity, an All-American Awards selection with multiple disease resistance.

A selection of 'Siberian Tiger', a cross between Beauty King and OSU Blue, developed by Mark McCaslin of Frogsleap Farm, Vermont

The next step for breeders was to take the best performers in other trials and incorporate them into their breeding lines to create a more well-rounded tomato. A major benefit in this effort was that many varieties were unrelated, and had excellent 'nicking' ability to create high vigor when hybridized.

The consumer desired a great tasting tomato with red flesh. The inside of the fruit needed to be red and not green. Retailers desired a flattened globe shape that doesn't roll off the shelf, with smooth shoulders so it can sit on the store shelf without bruising. Screening for quality characters was an important step in tomato breeding.

Black tomatoes originate from Russia and the Ukraine and its flavor is very rich and complex, very acidic with strong savory undertones. Tomato variety Black Plum, also known as Black Roma.

Aside from cracking and soft fruits, some of the wild species had other undesirable traits such as green gel, bitter fruits, large stem-end and blossom-end scars, a large woody core, bumpy shoulders, and also zipper fruits, a line from the top to bottom of fruits caused by a fusing of flower parts. By consistently culling individual plants without these undesirable traits, they could be removed from future generations.

List of Fruit Defects

Cracking – Radial and Concentric: genetic, nutritional, and environmental
Cat facing or Fasciation – incomplete pollination or cool temperatures and cloudy conditions during flowering and fruiting
Misshapen fruits
Stem end and blossom end scar, small stem core size – minimize discarded fruit slices
Puffiness-empty seed cavities caused by high or low temperatures, excessive fertilization. Genetic and environmental
Blossom End rot-commonly caused by calcium deficiency in combination with high N, insufficient water, heavy fruit load, and also genetic. Firmer fruits have a high Ca requirement.
Zipper fruits-line down the side of fruit related to dysfunctional pollination, but could have an environmental component.
Nipple Tips-genetic throwback undesirable when breeding non-nipple fruits
Blotchy Ripening- believed to be related to N:K balance, but can also be caused by white-fly vectored viruses.
Sun scald-poor foliage cover exposes fruits to sunburn.
Vascular Browning or Grey wall – blotches or grey color in skin believed to be related to poor gas escape from fruits, especially during overcast and no wind conditions.

Through a chance meeting at St. John Hall on the UH campus in 1976, I was able to work with Jim Gilbert in his last two years of research, reviewing all his research before assisting in field trials evaluating quality characteristics listed above in 93 Hawaii tomato lines.

Green shoulders are considered undesirable in mainstream markets because the consumer is buying red for their salad, but trends are changing to include new colors and shapes for the tomato of today.

Jim Gilbert was a key player in the STEP and also focused on the development of hybrids by incorporating Hawaii disease-resistant lines with varieties from the southeastern U.S., especially Florida and North and South Carolina. Hawaii disease resistant lines possessed some undesirable genetic traits related to fruit quality, but crossing with large-fruited *L. esculentum* types from other university programs helped to suppress undesirable traits inherent in wild species.

Challenges and successes of the STEP were highlighted in a paper “Hereditary Resistance of Disease in Tomato” by J.M. Walter. In a foot note on the introductory page, he states, *“The writer wishes to acknowledge the generous aid of numerous other tomato breeders in assembling the information presented in this article. To J.C. Gilbert, C.F. Andrus, and J.W. Stroebel, he is most indebted. The faith that the needed aid would be forthcoming was the only basis on which the task could be undertaken.”*

Producing grape, cherry, and mini roma tomatoes on Molokai for local sales.

The release of the Hawaii N-series hybrids incorporating disease resistance in a commercially acceptable tomato set the standard and took top honors in many of the university-sponsored trials throughout the southern states. Some of the UH hybrids were resistant to nine diseases, and yields of 100,000 pounds per acre far surpassed varieties grown under challenging tropical conditions.

They included N-52 (N for nematode resistance), a cross between Anahu and STEP 305, a selection developed by J.M. Walter at the University of Florida with resistance to Fusarium wilt Race I and II, and also Tobacco Mosaic Virus. When tested in competition with other tomatoes at 30 locations in the southern U.S. (1957-73), Anahu hybrids consistently excelled in both yield and adaptability.

Other widely used hybrids included N-5, N-11, N-56, N-65, and N-69. Improved TMV resistance was added in newer hybrids N-91 and N-93. The N hybrids also excelled in other parts of the world, including El Salvador, Israel, and Argentina. University of Florida tomato breeder J.M Walter acknowledges in his report that, *"Hawaii has led the way in the study and advancement of this root-knot resistance from L. peruvianum. Gilbert and his associates, including graduate students contributed rapidly to knowledge of the gene Mi from the genetic standpoint, fixed it in stocks that have proven extremely useful, especially Anahu, and combined it with as many as nine other resistances in numerous, prolific, widely-adapted hybrids."*

Open-pollinated varieties continued to be refined with the release in 1970 of Healani, an improved Anahu with increased resistance to TMV through the addition of the TM-2a gene, and tolerance to Vascular Browning, a physiological disorder associated with calm, cloudy weather during cooler months of the year and found especially in the Kona area. This disorder would subside with the return of trade winds. Healani was a cross between Anahu and STEP 305 refined over several generations then crossed to STEP 559 from South Carolina to improve fruit quality and size.

Seed production of Healani at the Volcano Research Station utilizing a hydroponic system.

Hawaii's contribution to the tomato world included not only root-knot nematode and TMV resistance, but also resistance to Bacterial Wilt. The development of the Bacterial Wilt resistant line, UH 7996 by Juan Acosta and Jim Gilbert created an

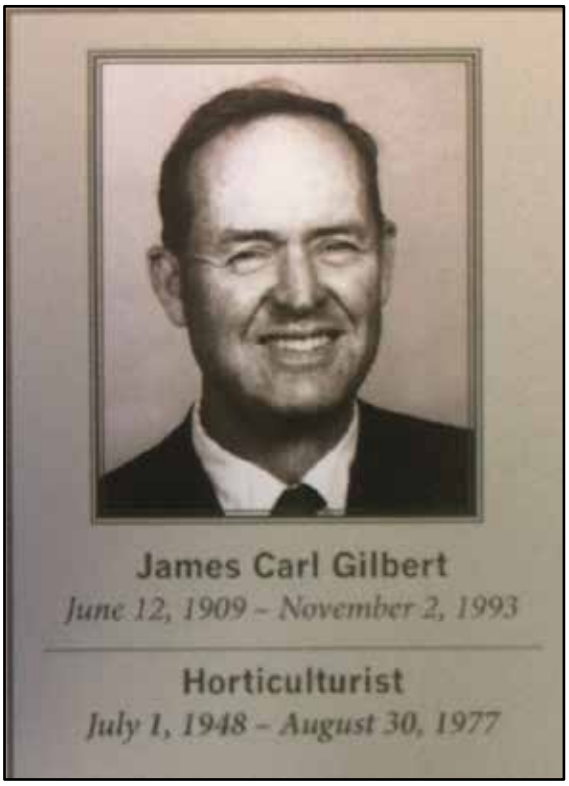
important stepping stone for the control of this disease.

Selections from the last year Jim Gilbert's research.

The release of Kewalo, a bacterial wilt-resistant variety also combined root-knot nematode and TMV resistance from Anahu and Kalohi with Fusarium and Stemphylium Grey Leaf Spot resistance. The hybrid BWN-21 combined Bacterial Wilt and Root-Knot Nematode resistance in a large fruit from Kewalo crossed with a North Carolina line.

Over 40 years after the retirement of Jim Gilbert, the tomato selection UH 7996 is still the most bacterial wilt resistant variety used in breeding programs throughout the world. Unable to determine the pedigree of UH 7996 due to a lack of records, an important prerequisite in tomato breeding, University of Florida tomato breeder Jay Scott laments, *"Breeding is an art as much as a science, and the exact pedigree of the most famous bacterial wilt resistant line Hawaii 7996 will probably remain the secret of the breeding genius of the late J.C. Gilbert".*

His last two disease-resistant Hawaii lines remained as numbered lines, including UH 8222 and UH 8248. They possessed most of the disease-resistance traits developed over the previous forty years, including improved resistance to TMV and enhanced fruit quality. Although determinate siblings, UH 8222 possessed a compact growth, habit with short internodes that allowed for the creation of compact indeterminate plants including N-101, the last of the N-series. Taste was one of the most important attributes Jim Gilbert screened for in each of his improved lines. It wasn't enough to possess resistance to several diseases if it didn't taste good. He retired in 1977.



Ken Takeda worked in the Hawaii tomato breeding program in the 1970's as a student, and 'inherited' the program after Jim Gilbert's retirement. He continued to improve Hawaii lines and also developed hybrids with STEP lines. Even after his retirement in 2002, Ken Takeda continued to hybridize and screen new tomato varieties at the Poamoho Research Station. Hopefully his new selections can be advanced to a commercial level in the near future.

Komohana Tomato from the Baker's Creek Website

Several years ago, County Extension Agents from the Big Island were involved in the development of a grape tomato with the release of Komohana, whose parental line originated from Taiwan. A grape tomato with thick flesh, a phenomenal shelf life, and good tolerance to foliar diseases, it was selected over several generations and refined in Hilo conditions at the Komohana Extension Center.

Where this story will end, nobody knows, because it's still unfolding. For well over two decades, a major redirection has been occurring due to a decrease in funding for vegetable breeding at the universities, and also less coordination between university breeders nationwide and globally than in generations past. Very few university tomato breeders exist, and the rules of the game have also changed. Within the realm of a university environment, agriculture is not seen as important as in generations past.

A focus on intellectual property and how to get the maximum return from your efforts in order to continue your research is the game changer. Today, the bulk of vegetable breeding has shifted to the private sector with the goal of increasing bottom lines and seeking residual revenue through patenting.

The collaborative and participatory breeding model is still relevant today as farmers become key players in crop improvement through field trials under varying farming systems, both conventional and organic. New technologies such as modeling and genetic mapping make breeding and selection more predictable so breeding programs can advance at a faster pace.

Tomato Yellow Leaf Curl Virus (TYLCV) is a serious disease in Hawaii today, and the only remedy is to grow resistant varieties.

New, emerging diseases such as Tomato Yellow Leaf Curl Virus and Pepper Mottle Virus, along with new strains of old diseases such as Tomato Spotted Wilt Virus will keep tomato breeders engaged for generations to come, even with advanced technologies.

In addition to disease resistance, the focus has diversified into bringing heirlooms into the mainstream, updating heirlooms with resistance to common diseases, new colors and color combinations, high antioxidant and high nutrient content, cold tolerance, earliness, low-input efficiency, increased shelf life, controlled ripening, new processing objectives, and an array of novel genetics.

With increased interest in heirloom tomatoes, many of the old UH varieties may experience a resurgence. Varieties that are

long gone may find a new place in Hawaii's home gardens, including Anahu, Pu'unui, Kolea-C, Kalohi, and others. Hawaii's tomato varieties will live on if they have utility in the modern world.

Heirloom tomatoes sold at Kauffman's Fruit Farm and Market in Lancaster, Pennsylvania

Beauty Mark, a variety developed by Tom Wagner is one of many striped varieties available to both commercial growers and home gardeners.

Hawaii Tomatoes Production Challenges Today

With the mutation of new races and strains of diseases, many diseases discussed here are still a threat to tomato growers in Hawaii. Spotted Wilt Virus is still a debilitating virus in many production areas of Hawaii. Spread by many species of Thrips, the disease is maintained in many weed hosts. Even with excellent weed control in and around crop fields, this disease can be a major threat.

Resistance to TSWV from the variety 'Pearl Harbor' held out until the 1960's when a new strain appeared. In the 1980's, with both TSWV-susceptible lettuce and tomato production in close proximity, some even in a rotation on some farms, there were major outbreaks in Kula, Maui. Lettuce production was also affected in Lalamilo on the Big Island and in Waianae on Oahu, and losses of 50–90% were experienced by farmers.

In the late 1980's, new TSWV resistant tomatoes varieties were being developed through the efforts of Dr. John Cho of the UH CTAHR Kula Research Station in collaboration with Petoseed. Today, the progeny of some of these lines are growing on Hawaii tomato farms.

Growing varieties TSWV resistant varieties is the best way to keep this disease in check. Breeders in the Southeast U.S. are working to develop varieties with resistance to new strains of the virus to bolster resistance to today's and tomorrow's threats. For more information on Tomato Spotted Wilt Virus, you can download this free publication: https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-81.pdf

The first outbreak of Tomato Yellow Leaf Curl Virus occurred in Israel in 1930. The virus reached California in 2007 and Hawaii in 2009. By the time this disease reached Hawaii, resistant varieties were already available for Hawaii tomato growers from commercial seed companies, especially those in Israel. This virus is a major threat to

Hawaii commercial tomato production today, and TYLCV resistance will need to be incorporated into varieties grown in Hawaii.

TYLCV-resistant determinate tomatoes from Israel in field trials at the Poamoho Research Station on Oahu.

For more information on TYLCV, you can download the following free publications:

https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-70.pdf
https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-78.pdf

Today, in addition to disease resistance, the focus has diversified into bringing heirlooms into the mainstream, creating heirlooms with resistance to diseases, new colors and color combinations, high antioxidant content, high nutrient content, cold tolerance, earliness, low-input efficiency, increased shelf life, controlled ripening, new processing objectives, and an array of novel genetics.

However, in order to survive and thrive in Hawaii's changing weather conditions, new varieties must be able to resist many of the diseases prevalent today, especially viruses since there's no control other than genetic resistance. New tomato varieties must be able to keep up with the pace of new diseases, both evolving and introduced.

Yellow tomatoes have a sweeter, less acidic taste than red tomatoes. Lower in Lycopene than red tomatoes, but higher in Folate, its texture is meatier than reds.

ACKNOWLEDGMENT: Mahalo to Dr. Richard Manshardt for his critical review of this newsletter. His assistance is greatly appreciated.

//\\//\\//\\//\\//\\//\\//\\//\\//\\//\\//\\//\\//

Well, that's it for this quarter! This quarterly brings back memories of working with Dr. Jim Gilbert at the Poamoho Research Station on Oahu in 1975 and 1976, walking through lines of 93 tomato selections, and evaluating each one for quality characteristics, and especially tasting the good, the bad, and the ugly. The taste of some of them never leaves your mouth! Enjoy the summer and take some time off to enjoy the great outdoors other than your farm!

//\\//\\//\\//\\//\\//\\//\\//\\//\\//\\//\\//\\//