Update on Genetic Engineering of Chinese Taro (variety Bun long) for Increased Disease Resistance

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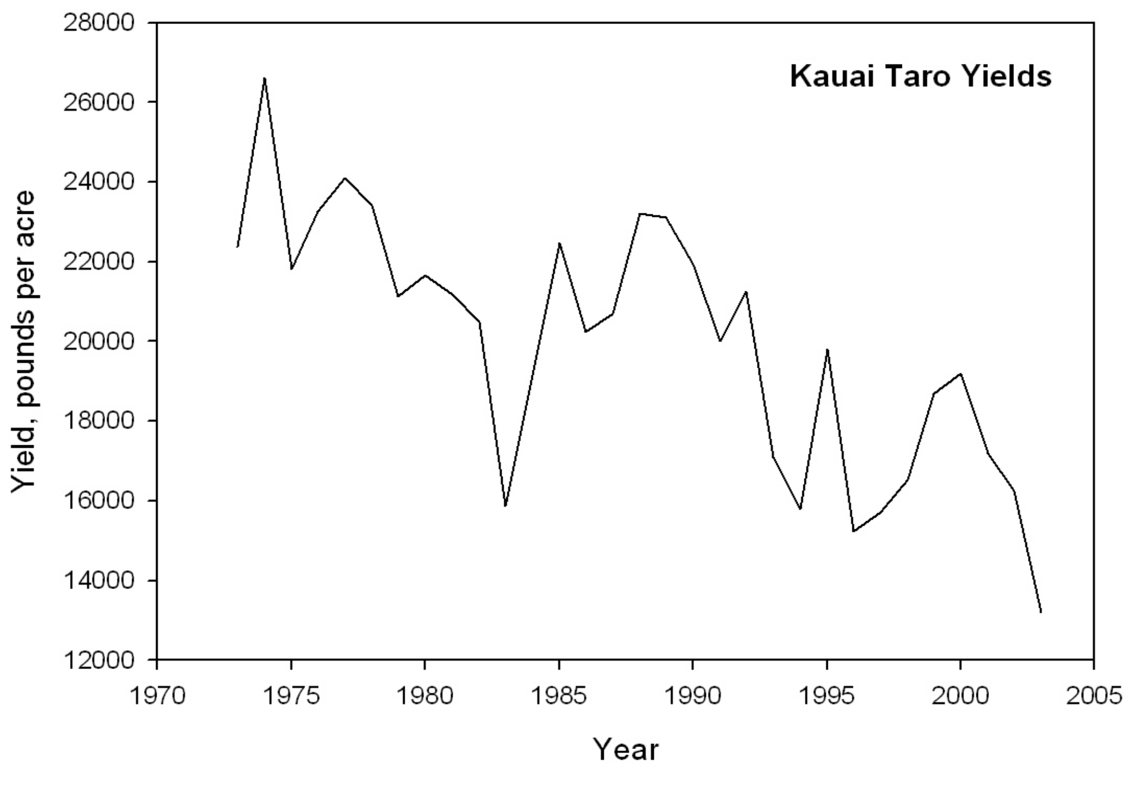
Why do we need to increase disease resistance in taro?

Hawaii is no longer the isolated island chain that it once was. Today, we have ships and airplanes arriving from places around the world, and unfortunately, they bring new diseases and pests. *Phytophthora* leaf blight reached our islands during the 1910's and probably caused losses of many traditional taro varieties. At one time, there were 343 named taro varieties in Hawaii[1], but less than 84 remain today. Many probably were lost due to introduced diseases and pests.

Taro yields in Hawaii have been declining over the past 50 years, with the lowest production since 1946 recorded in 2005 (http://the.honoluluadvertiser.com/article/2006/Feb/02/bz/FP602020320.html). In addition to the overall decrease in taro production (which partly is due to decreased acreage in production), yield on a per acre basis has declined also (figure below is based on the Statistics of Hawaiian Agriculture). Much of the recent sharp decreases in yield are due to diseases and pests, such as *Phytophthora* leaf blight, *Pythium* corm rots, pocket rot, and apple snails.



[1] E.S. Craighill Handy, 1940, The Hawaiian Planter, Vol. I, Bishop Museum Bulletin 161.

Phytophthora leaf blight

Pythium corm rot

Why utilize genetic engineering (GE) of taro to increase disease resistance?

Conventional breeding of taro is being conducted at the University of Hawaii, and new hybrids have been developed with increased resistance to *Phytophthora* leaf blight. However, under weather conditions suitable for this disease organism, this resistance can break down. The taro variety shown above with leaf blight is one of the new hybrids conventionally bred for greater disease resistance.

Genetic engineering offers the possibility of increased disease resistance beyond the level found within the taro germplasm. And, the taro variety remains the same genetically except for the few new genes engineered into it.

The greatest success of genetic engineering of crops for increased disease resistance has been to improve viral disease resistance in plant species without any known natural resistance. For example, genetic engineering of papaya for resistance to *Papaya ringspot virus* has helped to save the papaya industry in Hawaii.

The Alomae-Bobone viral complex is found in the Solomon Islands today, where it has wiped out 96% of the native taro varieties there and decreased taro production by 95%. Hawaiian taro varieties were tested in the Solomon Islands and all were found to be susceptible to this virus complex[2].The insect vector required to transmit this virus complex is found in Hawaii. Imagine if that virus reaches Hawaii - what would it do to our taro production?

Alomae, a lethal viral disease of taro, is spread by taro planthoppers.

In the Solomon Islands, "it is by no means certain that the crop [taro] can be reinstated to its former abundance and usage. Its day may have gone forever, as has happened in many parts of coastal Melanesia."[3] Could this viral disease decimate taro production in Hawaii in the future?

Is the movement of genes across species unnatural?

No. Conventional breeding of plants and animals have moved genes across species for specific purposes, such as increased hardiness. For example, mules are the offspring of a female horse and a male donkey. And triticale is a hybrid of wheat and rye. In addition, all organisms, including humans, carry genes inserted from different species. For example, all humans carry genes that have been incorporated from viral infections.

The bacterium *Agrobacterium tumefasciens* transfers its DNA (genetic material) into woody or herbaceous plants and causes crown gall disease. In our project, we are utilizing this naturally occurring bacterium to transfer disease resistance genes into Chinese taro.

What is the progress of our project on genetic engineering of Chinese taro to increase disease resistance?

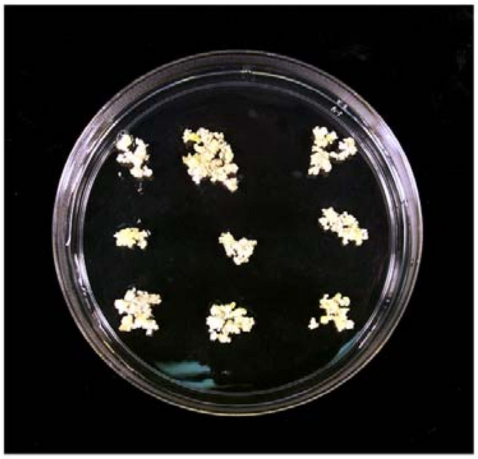
Three disease resistance genes have been transferred into Chinese taro variety Bun long:

1. Oxalate oxidase gene from wheat;
2. Chitinase gene from rice; and

[2] S. Pacific Commission., 1978, Advisory Leaflet.
[3] Kastom Gaden Association, Solomon Islands, 2005., People on the Edge, www.terracircle.org.au.

3. Stilbene synthase gene from grapevine.

Each disease-resistance gene was transferred separately into callus (undifferentiated tissue) of variety Bun long in tissue-culture. Then, we manipulated plant hormones to produce shoots and then whole plants from the callus.



Taro calli (undifferentiated tissue)

Taro plantlets in tissue-culture

<u>Do these disease resistance genes help Chinese taro resist pathogens?</u>

Yes, in preliminary tests using small, tissue-cultured plants.

Untransformed Chinese taro (NT) infected with *Phytophthora colocasiae* at 12 days after inoculation. Note plant is almost dead.

Chinese taro transformed with oxalate oxidase gene (g5) shows complete arrest of *Phytophthora colocasiae* without any diseased lesions spreading to the leaves.

Chinese taro transformed with an oxalate oxidase gene completely arrested the spread of the pathogen *Phytophthora colocasiae* which is the organism responsible for leaf blight. In comparison, untransformed Chinese taro was almost dead at 12 days after inoculation with the pathogen. Other preliminary tests showed that Chinese taro transformed with an oxalate oxidase gene or a chitinase gene slowed the spread of the fungal pathogen *Sclerotium rolfsii* but the disease eventually killed the plants.

<u>How do the products of these disease resistance genes work?</u>

Oxalate oxidase catalyzes the breakdown of oxalate to produce hydrogen peroxide which inhibits growth of pathogens. Remember the hydrogen peroxide your mother used to cleanse your skinned knees?

Chitin is a hard, semitransparent material that's found in the cell walls of some fungi and molds. Chitinases degrade the chitin found in the cell wall of fungal pathogens, causing the fungi to die.

Stilbene synthase catalyzes the production of resveratrol, a compound that is found naturally in grapes and peanuts. Resveratrol stops the growth of fungal pathogens.

<u>Could these disease-resistance genes accidentally move from GE Chinese taro?</u>

Not likely. First, Chinese taro variety Bun long rarely flowers under the environmental conditions of Hawaii. Second, traditional Hawaiian taro varieties rarely produce viable seed in Hawaii without human intervention. Taro breeders must manually move the pollen from one taro flower to another flower when its female part is ready because the insect that naturally pollinates taro flowers is not found here. Also, since taro is vegetatively propagated, it would be easy to maintain traditional taro varieties without a high risk of accidental transfer of disease-resistance genes from GE Chinese taro.

<u>How might these disease-resistance genes affect the nutrition of taro?</u>

The health risk of GE food is so low that after more than 10 years of experience, GE crops have been grown on more than a billion acres and been consumed by millions of humans without a single negative health issue[4]. The federal government requires intensive testing of genetically engineered crops for possible health and environmental hazards prior to approval.

The official position of the American Dietetic Association is that "Agricultural and food biotechnology can enhance the quality, safety, nutritional value, and variety of food available for human consumption and increase the efficiency of food production, food processing, and food distribution, and environmental and waste management"[5]. Did you know that if you eat cheese made in the United States, almost certainly you are eating the product of a genetically modified organism?

The anti-microbial compounds produced in GE Bun long should have little negative effect on its nutrition. For example, oxalate oxidase possibly might improve the

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[4] International Service for the Acquisition of Agri-Biotech Applications, 2006, Brief No. 34-2005.
[5] Journal of the American Dietetic Association, Feb. 2006, p. 285-293.

digestibility of taro, because it breaks down oxalate, a known anti-nutritive compound that contributes to the ‘itchiness’ of taro. Chitinases should have little effect on humans when consumed, because chitins are found in true fungi and insects but not in plants or mammals. Resveratrol is found in the skin of red grapes and it might *improve* the nutrition of GE Chinese taro due to its anti-cancer, anti-viral, and anti-inflammatory effects. Of course, prior to any potential commercialization of GE Chinese taro, federal government regulations require intensive food safety tests.

<u>What are the plans for GE Chinese taro when this project terminates?</u>

The early results for increased disease resistance of GE Chinese taro appear promising, but much more research is needed. Obviously, researchers cannot state that GE Chinese taro is more disease resistant without testing plants in the greenhouse and ultimately in the field. In addition, the federal government would require tests of GE Chinese taro for food safety and environmental concerns prior to commercialization.

This federally funded project on genetic engineering of Chinese taro for increased hardiness will run out of funds in early 2007. As a result of the current controversy about genetic engineering and taro, it isn’t likely that future funding will be available without support from the taro industry and/or consumers in Hawaii. Without further funding, the GE Chinese taro lines either must be discarded or sent to other cooperators in the world who are willing to conduct further tests. We will lose the opportunity in Hawaii to test these promising lines for increased disease resistance.

This brief summary presents the scientific facts about potential benefits such as increased hardiness of GE Chinese taro and an evaluation of possible risks. You, as taro consumers, need to weigh the possible risks against potential benefits of GE Chinese taro. Ask yourselves what risks are acceptable to ensure that taro is here for future generations to enjoy?