Forbidden Fruit: Transgenic Papaya in Thailand[1]

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Dressed in white, hooded "personal protection suits," Greenpeace activists donned goggles, gloves, and respiratory masks—the kind of dress you expect to see in the clean zone of a nanotechnology laboratory, not in a field in bucolic northeast Thailand. Easily bridging a barbed wire fence with a stepladder, they began pulling transgenic papaya (*Carica papaya*) from the trees, throwing the fruit into biohazard waste bins. The protestors stood for photographs—the press had been alerted—before a large yellow banner printed both in Thai and English that read: "Stop GMO Field Trials."

It was July 27, 2004—doomsday for agricultural biotechnology in Thailand. The protest at the Thai Department of Agriculture's (DOA) confined field trial set into motion a countrywide moratorium on all field testing of transgenic crops. Since the 1980s, the country had been a regional leader in developing a competitive biotechnology sector.

What went wrong? This is not an exceptional case. Since 1998, virus-resistant papaya had been grown widely in Hawaii, but had failed to be commercialized in many other places. This is despite the fact that genetically engineered or genetically modified (GE or GM) virus-resistant papaya is close to an ideal "pro-poor" GE crop.

The aim of this essay is to contrast the rapid and widespread adoption of transgenic papaya in Hawaii, where it saved an industry, with that of Thailand, where it has yet to be approved for commercialization—even though in some regions virus infection rates are as high as 100% and yields are dramatically reduced. Understanding the political and social factors that stymied this promising technology in Thailand may help in devising better strategies for introducing the next generation of biotechnology crops to other countries.

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AN UNRULY VIRUS

"What struck me in the beginning was that here was a way that was never before possible to combat a disease."—Carol Gonsalves, researcher.

The *Papaya ringspot virus* (PRSV) is transmitted by aphids and is the single-most threatening factor to papaya production worldwide (Gonsalves, 1998). Following infection, PRSV compromises the photosynthetic abilities of the upper leaves of the tree, leading to diminished vigor, stunted growth, and poor fruit quality. Ultimately, the plant dies.

PRSV was identified on the Hawaiian island of Oahu in the 1940s and became a significant threat to the industry in the 1950s. The industry was moved to the then virus-free island of Hawaii where it thrived in the climatically hospitable Puna region, producing 95% of Hawaiian papaya in the 1970's (D. Gonsalves et al., 2004). However, it was clear that the virus would eventually infest the island of Hawaii.

Key developments in the 1980s put virologist Dennis Gonsalves in a timely position to apply relatively new biotechnology tools to solve the PRSV problem. By that time, pathogen-derived resistance (PDR) had emerged as a promising strategy for controlling plant viruses, and viral coat proteins (CPs) had proven to be effective elicitors of PDR (Abel et al., 1986). Gonsalves and his collaborators developed a mild strain of PRSV for use in cross protection but had minimal success. With the cloning of the CP gene of PRSV, the development of the gene gun (Sanford et al., 1987), and advances in tissue culture, they were able to transform papaya with the CP gene. This approach was successful in rendering 'Sunset' papaya resistant to the virus (Gonsalves, 1998) and a homozygous line, named 'SunUp' was generated. Resistant SunUp was crossed with a more transformation-resistant variety that is preferred by Hawaiian growers: the yellow-fleshed variety 'Kapoho'. The resulting line was named 'Rainbow' (Gonsalves, 1998).

SUCCESS IN HAWAII

"For me I know the virus almost shut me down. I am not going to go back and plant non-transgenic papaya anymore. It's too much of a gamble."—Willie Julien, Hawaiian grower.

The field trial of the trangenic line began in 1992 on the infested island of Oahu, and by the end of that year the researchers reported that all nontransgenic papaya trees were infected, whereas the transgenics resisted the virus (D. Gonsalves et al., 2004). As feared, PRSV hopped islands and by 1995 the industry was in crisis, with trickle-down effects that threatened the economy of Hawaii (the Big Island) as a whole.

Fortunately, that year also marked the start of a large-scale in situ field trial of Rainbow (D. Gonsalves et al., 2004). The viral resistance of the transgenic plants directly demonstrated the promise of GE papaya to anxious growers, fruit packers, policy makers, regulators, and scientists. In 1996, the team began filing petitions with the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service and the U.S. Environmental Protection Agency to deregulate transgenic papaya and consulting with the U.S. Food and Drug Administration for food safety approval (Gonsalves, 2004). In 1998, seeds were made commercially available to Hawaiian farmers. The technology became available in time to save the industry, and the Papaya Administrative Committee (PAC) obtained regulatory approval before anti-GE campaigns gained household notoriety. Intellectual property rights and the freedom to operate were negotiated by Cornell University on behalf of the PAC (Cahoon, 2003). Among those battles were disputes over PDR, the use of antibiotic resistance genes and the 35S cauliflower mosaic virus promoter, and regaining the rights to use the gene gun after the technology had been licensed to DuPont (R. Cahoon, personal communication).

Once seeds were available to growers, adoption was remarkably rapid compared to other GE crops; within the first year, 98% of Puna growers had registered with the PAC to receive the seed, and 73% were growing it (C. Gonsalves et al., 2004). By the second year, 56% of the fruit-bearing acreage was transgenic. Small-scale growers (0.4–2.4 ha of papaya) adopted the technology most rapidly. Perhaps most significantly, the availability of GE papaya brought growers back into the papaya business after struggling to find other means of income during the epidemic (Gonsalves et al., 2007).

Adoption was rapid for several reasons: positive communication campaigns, farmer engagement during the research and development and field trials, distribution of approximately 1,134 kg of free seeds to registered growers, and the fact that the technology addressed an immediate problem affecting farmers' livelihoods (C. Gonsalves et al., 2004).

GE PAPAYA IN THE DEVELOPING WORLD

"Here people cannot afford vanity."—Dr. M. Abdul Momin, principal scientific officer, On-Farm Research Division, Bangladesh Agricultural Research Institute, Pabna.

Papaya is predominantly produced and consumed in the developing world. It is high in vitamin C and rich in pro-vitamin A carotenoids, both of which indirectly facilitate iron uptake. Thus, it helps alleviate two of the "big three" micronutrient deficiencies that plague undernourished people globally (iron, vitamin A, and iodine). A 100-g serving of ripe papaya (about one-quarter of a small Hawaiian papaya), provides 133% of the recommended daily intake of vitamin C for an adult and 33% of the recommended daily intake for vitamin A (Duxbury, 2003).

Papaya is consumed in the developing world as a fresh fruit, as a raw green vegetable in salads, and as a cooked vegetable. Although produced on a commercial scale in many developing countries, papaya is also a popular crop in the backyard kitchen gardens of subsistence farmers because it is easily grown from seed, produces fruit within the first year after planting, and requires few inputs. Although a minor crop by global commodity standards, papaya holds considerable promise for diversifying the diet of the rural poor in tropical countries. Unfortunately, in most countries, papaya suffers from PRSV, limiting its productivity commercially, as well as in the backyard (Gonsalves et al., 2007).

The developers of the first transgenic papaya envisaged the GE variety as a promising pro-poor product of biotechnology and were eager to collaborate with researchers from around the developing world. Suitable GE, virus-resistant varieties have now been developed for Brazil, Jamaica, Venezuela, Thailand, China, and The Philippines, among other countries. Yet, in no place outside Hawaii have growers or consumers reaped the benefits of these plants. In a recent article, Gonsalves and her colleagues (2007) highlighted how many challenges that developing countries face during adoption of GE papaya were overcome in Hawaii. The authors argue that this technology is particularly suitable for low-income farmers. With regard to consumer demand, the nutritional value of papaya—while important to Hawaiian consumers—is even more crucial in developing countries where papaya is already popular. GE papaya does not require changes in management practices or large capital investments, it does not alter production costs, and access to intellectual property is already being negotiated in several countries in a philanthropic manner (Gonsalves et al., 2007). Because the effects of PRSV have been as devastating in other countries as they were in Hawaii, there is a clear need for a solution, and a demand by increasingly vocal growers.

A FAILURE TO ADOPT

"Papaya is being devastated and we have a solution right here. It all comes down to political will. If you want to have impact, you have to be political. That is the essence of modern life."—Dennis Gonsalves.

If papaya is such a promising transgenic crop, why is it not being grown across the tropics? Although the reasons vary to some degree from country to country, prominent themes emerge globally. There is a lack of farmer engagement in the debate, and to the extent that networking with farmers does occur, it is often dominated by anti-GE nongovernmental organization (NGO) networks and less by government or university extension agents. Many developing countries still lack biosafety laws and too often countries lack sufficient infrastructure and training to carry out the regulatory testing needed prior to commercialization. Fear of biopiracy by foreign entities is directly tied to concerns over intellectual property because most of the intellectual property has been developed and previously implemented in wealthier nations. Finally, many countries' markets are dependent on the political and consumer demands of importing countries. Some understanding of how these hurdles have obstructed the adoption of GE papaya in developing countries can be gained by examining the case in Thailand, which in many regards has become the hotbed for the controversy around GE PRSV-resistant papaya. There it has become the poster child, both literally and figuratively, for the debate over agricultural biotechnology in general.

THE BATTLE OVER GE PAPAYA IN THAILAND

"The controversy in Thailand [over papaya] between the government and a small group of activists is making things slow down in our country and is only getting worse."—Vilai Prasartsee, director, Khon Kaen Plant Material and Technical Service Center, Thai DOA.

Thailand is a major food exporter and a regional leader in intellectual manpower and technical resources. The country embraced genetic engineering early on and, relative to other developing countries, a lack of infrastructure has not been the primary obstacle to biotechnology crop adoption. The Plant Genetic and Engineering Unit, located on the Kampaengsaen campus of Kasetsart University, first applied advanced techniques in biotechnology in 1985 (Sriwatanapongse et al., 2007). In subsequent years, many GE crops were developed in the country and 40 transgenic crops were approved for study in Thailand during the period from 1992 to 2000 (Sriwatanapongse et al., 2007).

Papaya is grown in all regions of Thailand at the commercial level, and by small-scale farmers who typically plant papaya trees in backyard gardens or peripheral to paddy fields. Thailand produces less than 2% of the world's papaya crop, and ranks as the world's 12th largest producer (Sriwatanapongse et al., 2007). Ninety percent of all papaya grown in Thailand is consumed domestically, and the remainder is exported as canned fruit salad (Sriwatanapongse et al., 2007). Beyond its nutritional value, papaya is an important food culturally; it is not uncommon for Thai people to consume green papaya salad, som tam, daily, particularly in the northeast region of Isaan.

As in most countries, the greatest limitation to papaya production in Thailand is PRSV, first observed there in 1975 (Sriwatanapongse et al., 2007). In 1981 Vilai Prasartsee, a researcher with the Thai DOA, initiated efforts to control the virus through an eradication program (Thitiprasert, 2003). Although this seemed a viable solution, the reluctance of villagers to cut down infected trees that had already set fruit limited its success (V. Prasartsee, personal communication). In 1986, Prasartsee contacted Gonsalves who was experimenting at the time with cross protection. With funds from the U.S. Agency for International Development and the Thai Ministry of Agriculture and Cooperatives, they began a collaboration that paralleled efforts for Hawaii. In 1995, two scientists from Thailand went to the Gonsalves laboratory at Cornell to develop GE PRSV-resistant lines. Two Thai-preferred varieties were transformed using microprojectile bombardment. The construct contained a nontranslatable CP gene isolated from a Thai strain of the virus. Because the CP is not translated, no detectable amounts of foreign CP are present in the transformed papaya (Sakuanrungsirikul et al., 2005).

In 1997, further breeding efforts continued in greenhouses, and confined field trials were conducted from 1999 until 2004, when they were banned. Third-generation lines from both varieties were 97% to 100% resistant to the virus. In addition, the Thai group began assessing the safety of GE papaya. Between 2001 and 2004, six sets of experiments were conducted that showed no ecological effects of GE papaya on adjacent non-GE trees, microbial flora, beneficial insects, or the surrounding soil. No differences in nutritional quality were found, no allergenic proteins or toxic attributes were observed, and rats fed GE papaya did not show any abnormalities (Sakuanrungsirikul et al., 2005).

The July, 2004 Greenpeace protest undermined the previous decade of research. There, Greenpeace charged that GE papaya had been distributed beyond the confines of the field trial under the negligence of the DOA, and presented evidence of the antibiotic resistance gene *nptII* and the 35S cauliflower mosaic virus promoter in papaya being grown illegally by farmers in 37 provinces (Wongruang, 2004). The DOA responded by charging two Greenpeace campaigners with trespassing, theft, and destruction of property; the activists were acquitted in 2006. In September, 2004, the agriculture minister confirmed the seed leak when one sample of 239 from farmers who had purchased what was assumed to be non-GE papaya from the research station tested positive (Samabuddhi, 2004a). The minister ordered the eradication of all trees on the test-positive farm, and testing of plants from all 2,600 registered recipients of papaya seeds from the station. As a final blow, he ordered the destruction of the field trial at Tha Pra. Station workers cut down all of the trees in the 1.8-ha plot and buried the plant material in pits onsite. The prime minister ordered the destruction of all field trials in the country, following a cabinet decision to place a moratorium on all confined field trials in Thailand in addition to the 2001 ban on open field trials. This brought research on agricultural biotechnology practically to a standstill (Sriwatanapongse et al., 2007).

During the period from 2005 to 2006, the battle between Greenpeace and the DOA took place primarily in Thai courtrooms. Despite the ongoing hearings, the National Policy on Biotechnology Committee, chaired by then Prime Minster Thaksin Shinawatra, submitted a draft of the National Policy on Biotechnology in 2005, though the policy specific to the application of genetic engineering is still pending (Sriwatanapongse et al., 2007). A draft of the National Biosafety Law, ultimately overseen by the Ministry of Natural Resources and Environment, was completed in 2005 and has been under public review since that date (Sriwatanapongse et al., 2007).

On September 19, 2006, the Thaksin government was ousted overnight in a quick coup d'état, which severely delayed any progress toward passing legislation on biotechnology. However, the interim post-coup government put a biotechnology advocate, plant virologist Dr. Thira Sutabutra, in the post of Minister of Agriculture. The Ministry's attempts to move toward lifting the moratorium were thwarted by demonstrators throughout 2007. Thira was scheduled to submit a proposal to the Thai cabinet to lift the ban on August 28, 2007. However, before he reached the cabinet meeting, Greenpeace dumped roughly 10 metric tons of papaya in front of the Ministry of Agriculture building. The activity was effective in delaying the meeting item, but the chaos that ensued outside the ministry was a fascinating test of consumer acceptance of GE papaya. Despite protesters dressed as "GMO zombie" fruits and alien eyeballs, passers-by reportedly pilfered as much of the papaya as they could (Bangkok Post, 2007a). Almost certainly, the papaya was not transgenic, but the consumer message was clear and widely reported as a "backfire" on the Greenpeace activity. With little time left in his interim post, Thira made his final push on December 25, just 2 d after the 2007 Thai general election. The cabinet turned down a proposal to end the 2001 moratorium, deciding to leave the decision to the next administration (Bangkok Post, 2007b). However, the cabinet did put forth a compromise resolution that will allow limited field trials in government-secured facilities. Each application must be approved by the cabinet and will be open for public review—obstacles that may make field trials practically impossible. What's more, it remains to be determined whether the resolution will hold up in court.

PLAYERS IN THE GE PAPAYA CONTROVERSY

Farmers

"Yes, I have grown GE papaya. I received it from my brother. People told him if he ate it, he would be infertile. However, I ate the fruits from this papaya and they are delicious."—an Isaan farmer.

The DOA was not the only victim of Greenpeace's 2004 activity. Farmers who purchased non-GE seed from the station were those whose livelihoods were most immediately affected (Wongruang, 2004; V. Prasartsee, personal communication). The story below illustrates what happened to a particular grower following the 2004 events. Her experience in many ways parallels that of other small farmers who found themselves in the crossfire.

Mrs. Somkuan Sriwongchotisakul is a 55-year-old widow with a 4.8-ha orchard on her mixed farm outside a small village in the heart of Isaan. Sriwongchotisakul took out an 80,000 Thai baht loan (currently valued at $2,555 in U.S. dollars) for labor and materials needed for papaya cultivation (S. Sriwongchotisakul, personal communication). In 2003, Sriwongchotisakul, leading a cooperative of 50 village members, purchased 5,000 supposedly non-GE papaya seedlings from the station and was registered as a seed recipient (Samabuddhi, 2004b). Several months later, Greenpeace GE campaigners came to her farm to sample her trees and confirm that Sriwongchotisakul had obtained seeds from the Tha Pra station. The day after the protest at Tha Pra, a group came to collect samples of her fruits and left with several bags for testing. Subsequently, Greenpeace announced that it was GE papaya.

Following this finding, the village chief announced to Sriwongchotisakul's neighbors that her papaya was illegal and harmful to human health "There were posters that said that this papaya was Dracula and if anyone eats it they will die," Sriwongchotisakul recalled. Local officials ordered the destruction of her trees. Sriwongchotisakul has since abandoned her plan to earn a living growing papaya and selling som tam locally; however, her unpaid bank loan looms large. The animosity between her and many of the villagers remains and she has largely removed herself from village social life (S. Sriwongchotisakul, personal communication).

Despite the impact that GE papaya had on farmers like Sriwongchotisakul, who were targeted during the 2004 event, most small-scale farmers in her position have little to no knowledge of GE crops. Responses from a study undertaken by the Foreign Agricultural Service of the USDA (USDA, 2005), indicated that 38% of northeastern farmers were unaware of the meaning of GE papaya. Sixty-four percent claimed to be aware of the technology, but only 37% had a correct understanding. In a study 2 years later, I found that whereas only 55% of farmers were familiar with the Thai term for PRSV, 95% said their trees suffered from the described symptoms (S.N. Davidson, unpublished data). When asked if they had heard of traditional breeding techniques to make hybrids, 55% said they had. Ninety-four percent of respondents approved of the technique, 3% did not, and another 3% were unsure. When asked if they had heard of genetic engineering, 30% said they had. Despite this low number, after the concept was explained, 81% of farmers approved of the methods, 5% did not, and 14% were unsure. When asked what they associated with genetic engineering methods, many declined to respond because they were not familiar with them. Those who did respond made overwhelmingly positive associations, using words like "development," "progression," "getting rich," and "abundance of fruit." Eighty-five percent of farmers said they would plant GE papaya if it were resistant to the disease. Ten percent were unsure if they would plant it and 5% said they already had planted GE papaya. No farmers said they would not plant it.

The Opposition

"Technology that isn't Thai isn't good for Thailand."—Natwipha Ewasakul, GE campaigner, Greenpeace Southeast Asia.

The activities of the multinational arms of Greenpeace International (GPI) have weighed heavily on the controversy around GE papaya in Thailand. It is arguable that without the influence, both financial and ideological, of the European-based group, the cabinet's ban on GE crops may never have come to pass. Thus, in considering the case of GE papaya in Thailand, it is important to understand the role that this particular organization has played in rendering the papaya a forbidden fruit.

The regional Greenpeace offices worldwide operate like franchises of the larger GPI organization in the Netherlands. Regional offices subscribe to a locally relevant subset of campaigns put forth by GPI, and to varying degrees are financially dependent on GPI. According to Jiragorn Gajaseni, who served as executive director of Greenpeace Southeast Asia (GPSEA) from 2000 to 2004, Bangkok-based GPSEA receives roughly 90% of its annual operating costs from GPI. According to Gajaseni, Bangkok was chosen as the home of the southeast Asia office because it offered financial and political support (J. Gajaseni, personal communication). Approximately 200,000 people in urban Bangkok donate an average of 100 baht ($3.20 in U.S. dollars) per month (J. Gajaseni, personal communication). Also, at that time Thailand was open politically and had a relatively free press. "But in countries like Vietnam," Gajaseni explained, "you could not do the Greenpeace kinds of campaigns, Greenpeace style." The strategic development of GPSEA's campaigns in Thailand has followed a growth-by-success pattern. Early on, Gajaseni canceled a campaign on forest protection and focused on the anti-GE campaign because their campaigners were successful in attracting media attention, boosting the image of the Greenpeace brand (J. Gajaseni, personal communication). Gajaseni calls the campaign against GE papaya one of the "highlights of Greenpeace Southeast Asia."

Gajaseni readily admits that Greenpeace's style of campaign can be "too radical for Thai people." But according to him, campaigning in a more culturally sensitive way was not effective. They focus on networking and an "aggressive" strategy (J. Gajaseni, personal communication). "We have to hit the right spot," Gajaseni explained. Determining how and where to hit is decided during annual assessments of each campaign. "In the [2004] Khon Kaen example, it was very clear… It was the biggest [field trial]," Gajaseni said. He continued, "If you hit the Tha Pra research station and hit GMO papaya where [papaya] is the basic food for Isaan people, you can be more effective." Gajaseni explained, "After our campaign in Isaan there were a lot of local organizations that raised hell about the GE papaya as well as to the government." He concluded, "We are catalysts."

Although fighting the zero-tolerance policies of Greenpeace may seem a daunting endeavor for scientists, not all anti-GE advocacy groups are as hardheaded. BioThai is a homegrown Bangkok-based watchdog group founded in 1995 to preserve Thailand's rich biodiversity. Although in principle the group is opposed to genetic engineering, their outlook is not as narrow as Greenpeace's zero-tolerance policy. BioThai Director Wintoon Lianchamroon explains, "In reality, we are still working within this country and we have friends in the academy who have invested many years of research on GE crops so we have to work with them so they can do their work…so we ask them to keep it in the laboratory or greenhouse… This is different from Greenpeace." The group separates itself from Greenpeace on cultural grounds as well. "Greenpeace is an international NGO… There may be some cases when they don't know the cultural situation or the political or economic situation in this country or the culture of the local people. We have to think a lot about these factors before we launch our own lobby work," Lianchamroon said. Although BioThai often collaborates with Greenpeace as well as other NGOs in Thailand, its modus operandi is distinct. "There are some cases, which we cannot do. The case of when they destroyed the papaya, this we cannot do, mostly due to our [Thai] culture," Lianchamroon explained (W. Lianchamroon, personal communication).

The Media

"GM Food Not Safe, Warns US Campaigner."—December 3, 2007 headline, Bangkok Post.

The Thai press is currently categorized by Freedom House as "partly free" and thus coverage of controversial issues such as genetic engineering is not due to lack of press freedom. GPSEA's increasing momentum is reflected in the media's coverage of GE papaya and the government's wavering position on biotechnology crops.

The Thai media coverage of GE papaya was low from 2001 to 2002, but subsequently underwent a "hoopla effect" in 2004 (Xiang, 2007, p. 34), precipitated by Greenpeace's accusations that the DOA released transgenic papaya seeds from the Tha Pra research station. This acted as a "trigger" event in media coverage of GE papaya in the second half of that year, and it remained a hot topic for some time (Xiang, 2007, p. 34). In 2005, when Greenpeace and the DOA were in court hearings, coverage dropped. It picked up again in 2007 as Greenpeace pushed to prevent the cabinet from lifting the ban on field trials in late August and again in December, prior to the general election.

In a comparative analysis of media coverage of GE crops in China (GE rice [*Oryza sativa*]), Thailand (GE papaya), and the U.S. (GE rice and papaya), Xiang (2007) found that stories in the Thai press demonstrated the most negative attitudes toward GE crops, likely due to the intense use of anti-GE advocacy groups, such as Greenpeace, as news sources. Xiang (2007) observed that American newspapers reporting on GE papaya were more likely to cite scientific journals, industry representatives, and farmers than their counterparts in Thailand. In contrast, Thai newspapers overwhelmingly cited advocacy groups whereas scientists were the least frequently cited.

THE INTELLECTUAL PROPERTY ISSUE

"The secrecy surrounding US patents on Thai GE papaya—including the new patents now in process—adds to the unknown risks that this genetic experiment poses to Thai farmers, consumers and the environment."—Greenpeace SEAsia Web site.

Issues relating to intellectual property have further fueled the debate. In the Thai media, the Cornell Research Foundation (CRF), which handles intellectual property issues at Cornell University, has come under scrutiny, spurred largely by accusations from activist groups that Cornell is stealing Thai property: the CP gene sequence from the Thai PRSV isolate (Greenpeace Southeast Asia, 2004).

Because the molecular work was conducted in laboratories at Cornell, that university assumed the sequence as its own intellectual property. CP sequences from isolates brought by researchers from other countries, such as Jamaica, Venezuela, and Brazil, were also covered by the patent that CRF filed (R. Cahoon, personal communication).

Dennis Gonsalves and Richard Cahoon, director of CRF, foresaw the problem that the PAC and other collaborating countries would not necessarily have the resources or political leverage to obtain technology licenses on their own (Cahoon, 2003). In negotiating the rights to use the technologies for Hawaii (most of it owned by entities other than Cornell), the CRF arranged for the technology to be available to other countries. CRF acquired the licenses in each case, and could then legally transfer to each of the collaborating partners. CRF subsequently transferred the licenses to the PAC and drew up a memorandum of understanding (MOU) with the DOA in Thailand (R. Cahoon, personal communication). The MOU with Thailand distinguishes humanitarian from commercial use. According to the agreement, small farmers fall under the category of humanitarian users and should be able to use this technology without paying royalties. The exact definition of commercial use is left up to the DOA in Thailand but should include any fruit that is exported (Cahoon, 2003). At the time of the 2004 Greenpeace activity, the DOA was expected to sign the drafted MOU (R. Cahoon, personal communication). The MOU remains unsigned.

THE PRO-POOR GATEWAY CROP

All stakeholders involved, be they from industry, academia, or anti-GE activist groups, agree that in Thailand the battle over GE papaya is the one to win. They all see bioengineered papaya as a "gateway crop"—a forerunner for other GE crops. Greenpeace views all GE crops as a threat to the safety of the world's food supply. On the other hand, members of the foreign seed sector, though not directly involved in developing the DOA's transgenic papaya, are promoting the promise of the farmer-friendly papaya, hoping it may open the doors for their own products. Former GPSEA Director Jiragorn Gajaseni explains his position, "Papaya is nothing. But the reason why the biotech [sector] is pushing for the papaya is because they want papaya as a front leader to open the gates for another big crop in this part of the world. This is rice". Gajaseni admits (J. Gajaseni, personal communication) that the researchers in Tha Pra are "simply a small part of that." He adds, "That Tha Pra got targeted is just bad luck [for them]." So if even a pro-poor, best-case scenario crop cannot make it through the barricades of anti-GE activists, where is the hope for the next generation of biotechnology crops?

THE NEXT GENERATION OF BIOTECHNOLOGY CROPS MEETS THE NEXT GENERATION OF PLANT BIOLOGISTS

"I still feel this void since we still haven't fully transferred the technology to developing countries and I fear time is running out on me. That's my main unsolved challenge."—Dennis Gonsalves.

I would argue that hope for the next generation of biotechnology crops can be found in lessons from the previous one. What transpired in Thailand provides take-home messages that could provide scientists with insights on how to transfer the benefits of their research from the laboratory to the farmers and consumers who need it most.

Cultural awareness is essential. Assessing farmer needs provides insight into whether the technology in question is solving a problem that farmers confront, and whether they are likely to adopt the technology. By employing the same grassroots networking strategies that opponents to genetic engineering have used so effectively, relationships with local growers can be established, aiding cross-cultural understanding. This was a major difference between the Hawaii and Thai situations. Engaging growers, as was done in Hawaii, develops channels for effective education campaigns.

Farmers are some of the most eager adopters of new technology if they see it as a means of rising beyond their current standard of living—but they need to hear about it. Technology generated domestically is much more readily embraced by developing countries than those perceived as foreign, as demonstrated by the case in the Philippines (R. Hautea, personal communication). Collaborating with regional researchers and promoting technology development in-country also fosters the future capacity of the country in question.

Economic factors weigh heavily. It is estimated that if GE papaya were adopted in Thailand and production returned to historical peak levels, yields would increase by 471% and the annual economic benefit for Thailand would be roughly $880 million in U.S. dollars (Sriwatanapongse et al., 2007). Considering export markets is also critical. In the case of Thailand, 90% of the papaya is consumed domestically. Yet a portion of the 10% exported as canned fruit salad goes to Europe, which places constraints on the industry as a whole.

Political policies are just as crucial. The absence of biosafety laws can make it easier for anti-GE groups to claim that crops will be introduced injudiciously. If the country lacks the infrastructure and technical know-how to conduct regulatory testing, it is important to ask who will steward the technology through those necessary steps.

Finally, it is time to meet the press. Although scientists are not generally trained in media communication, who is better qualified to discuss the risks and benefits of GE crops? If scientists do not undertake this task, where will the public get its information?

If the next generation of biotechnology crops is to make an impact on those who arguably have the most to gain and have yet to reap the benefits of the first generation—those of the developing world—then it is time for plant biotechnologists to move beyond the bench, kick around in some barren soils, man a water buffalo for a day, meet the people whose lives will be impacted, and display the same amount of passion for having their technology used in the field as they have for developing it in the laboratory. It is time to get organized, get political, get heard, and get out of the lab. Otherwise, the fruits of this fascinating research may remain forbidden.

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