Transgenic Papaya Story: Still a Public-Sector Anomaly?

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I spoke at NABC 15[1], when the title of my talk was *The Papaya Story: A Special Case or a Generic Approach?* In the mid-1980s when we developed the transgenic approach, Roger Beachy and I were at the epitome of intellectual excitement. We believed that, in 10 years, the major crops would be improved through genetic engineering. The technology that led to the development of virus-resistant papaya is beautiful, and yet when I end my talks these days, I ask, "Really, what has happened over the past 25 years?" If we don't address that question seriously, I'll guarantee you that in 10 years or even 25 years from now we will be asking, "What happened?" At the end of my talk, we'll see whether my transgenic papaya story is a public-sector anomaly, or whether that approach is widespread.

Figure 1 shows a beautiful, delicious Hawaiian papaya. Roger Beachy and I became virologists because we wanted to fight virus diseases. Figure 2 shows the symptoms of

Figure 1. Virus-free papaya in Hawaii.

[1] *Biotechnology: Science and Society at a Crossroad.*

Figure 2. Papaya infected with ring-spot virus.

papaya ring-spot virus (PRSV), which has been in Hawaii since 1945. No natural resistance exists, and it is spread rapidly by insects.

Advance of PRSV

In 1978, the dean of the College of Agriculture pointed out to me that the virus—having destroyed the papaya industry in Oahu—had been identified in Hilo, just 19 miles from Puna where 95% of Hawaii's papaya's was grown (Figure 3).

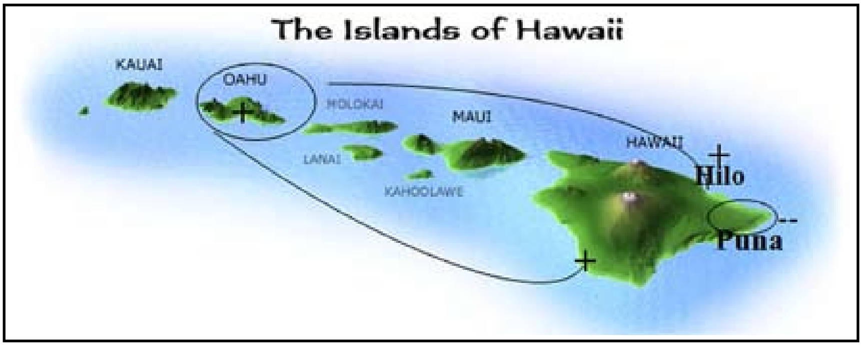


Figure 3. The potential problem.

He suggested that I do some research to try to develop a means of control. So, way back then, in 1978, we started by working up a rapid detection method, and then developed the pathogen-derived resistance method that Roger Beachy talked about[2]. Basically, by the mid-1980s the concept (Figure 4) had been proven with virus-resistant tomato.

[2]Pages 19–28.

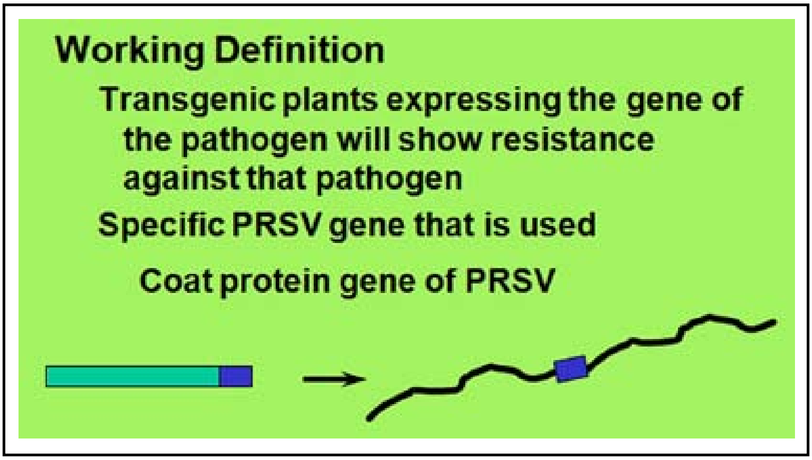


Figure 4. Pathogen-derived resistance.

We decided to take the coat-protein gene of the virus and place it in the chromosome of the papaya, in the hope that it would induce resistance, although, back then, in 1984 when we started, DNA sequencing was difficult as was cloning. And the dogma at that time was that resistance was coat-protein mediated, whereas our papaya ringspot had no natural start signal. So we actually added some amino acids from the cucumber mosaic virus to achieve a start signal.

I was fortunate in being at Cornell's Geneva Experiment Station, where John Sanford and his colleague had invented the gene gun. With Jerry Slightom, an excellent molecular biologist, and graduate student Maureen Fitch, we cloned the coat-protein gene in 1984, and Figure 5 shows the "father" of the gene gun in 1988. We were still using .22-caliber blanks to shoot in genes.

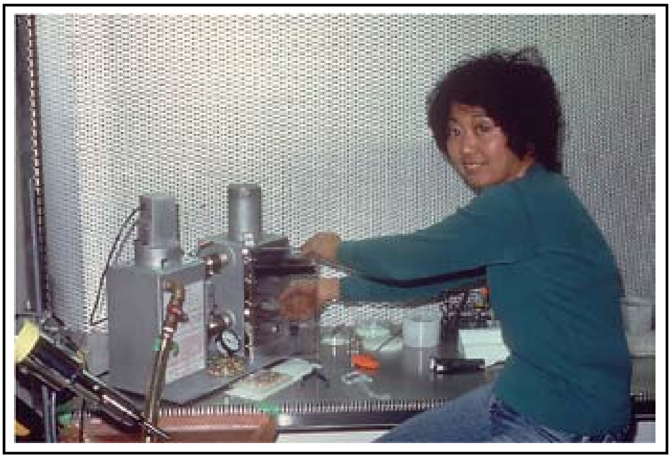


Figure 5. 1988–89, Maureen Fitch using the gene gun to transform papaya.

First Virus-Resistant Papaya

Figure 6 shows a picture—taken at Cornell University in April 1991—of transgenic papaya line 55-1, which was a non-transgenic 'Sunset' transformed with the coat-protein gene inoculated with virus; the plant on the left contained the viral coat protein. This is where our group philosophy differed from the conventional wisdom of finding out if progeny indicated single-gene resistance. Instead, we cloned plants from tissue-culture, put them in the field and, within a year, our first trial was in progress.

Figure 6. 1991: Virus-infected papaya, genetically engineered plant on left.

By April 1992, cloned plants of this line were in the field in Oahu to see if resistance occurred. The long-awaited presence of the virus in Puna was reported in May 1992. Figure 7 shows devastation that occurred in 1994.

Figure 7. Puna: 1994.

Having proven the concept, Richard Mashardt backcrossed the female line 55-1 with the non-transgenic sibling Sunset until line 55-1 was homozygous for the coat-protein gene; he called this cultivar 'SunUp.' Growers wanted yellow flesh, so he made an F1 hybrid of 'SunUp' and non-transgenic 'Kapoho' to come up with transgenic 'Rainbow'

Figure 8. Transgenic 'Rainbow' surrounded by non-transgenic papaya.

papaya. He utilized the field of less than an acre at the Waimanalo Experiment Station on Oahu to develop all this within three years of our first field test in May 1992.

Figure 8 shows a solid block of transgenic ‘Rainbow’ surrounded by a non-transgenic line in a field trial in Kapoho. There was no question that the transgenic approach was working, and growers saw it and requested it. We told them that they could not have it until after deregulation. But who would finance the deregulation of a public-sector project? John Sanford and I applied for an NSF grant, without success. The team’s first grant for the papaya work was for about $25,000.00 for three years—special funds through Senator Inouye—it was no million dollars.

Red Zone and Release

So, we scientists entered the “red zone” (Figure 9). I had never done any regulatory work, but it was necessary if we were to help the growers. Back then it was easier than it is today; the process is represented in Figure 10. I recall a meeting when growers suggested that the technology would be too expensive for their adoption because Monsanto would likely charge $10 million. They had read that in the newspaper. Within a year, the Papaya Administrative Committee (PAC) had the license, and Monsanto did not charge a dime for it, showing that it’s a mistake to rationalize yourself out of doing something.

In May of 1998, almost 6 years to the day after the virus was discovered in Puna, we were able to release seed to growers. If we had started our research after the virus had reached Puna there would be no papaya industry in Hawaii today. I’m not a philosopher, but I would say that if, under the best circumstances, something is likely to take time, start on it immediately. If timing is critical, don’t wait until you have the ultimate answer. Use best judgment and move forward (Figure 11).

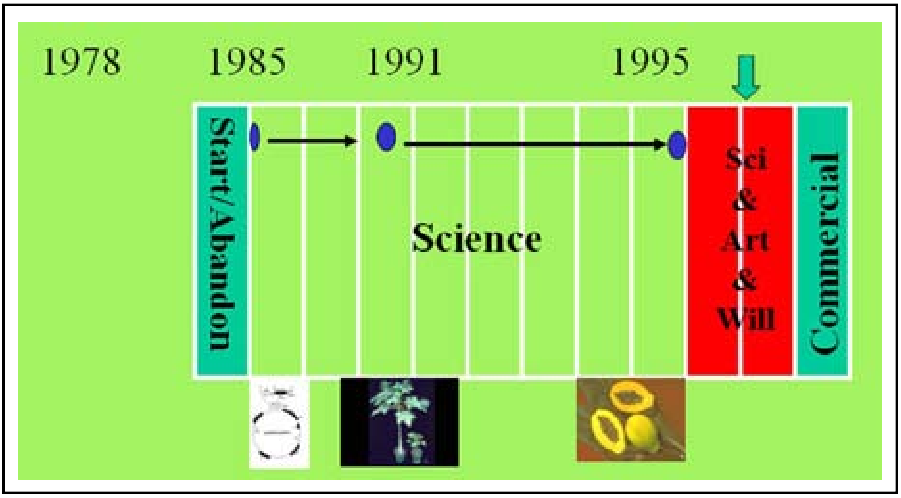


Figure 9. Hawaiian transgenic papaya (1995):
Entering the red zone of translational biotechnology.

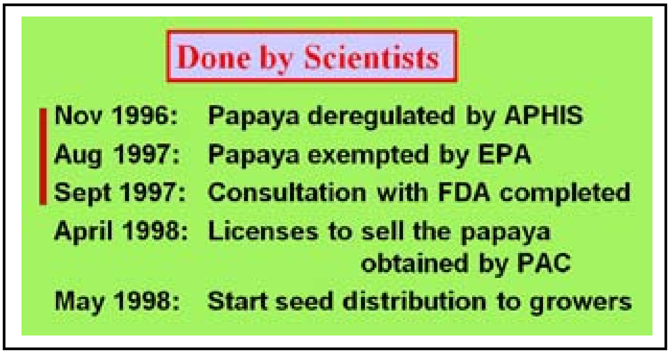


Figure 10. Deregulation and commercialization.

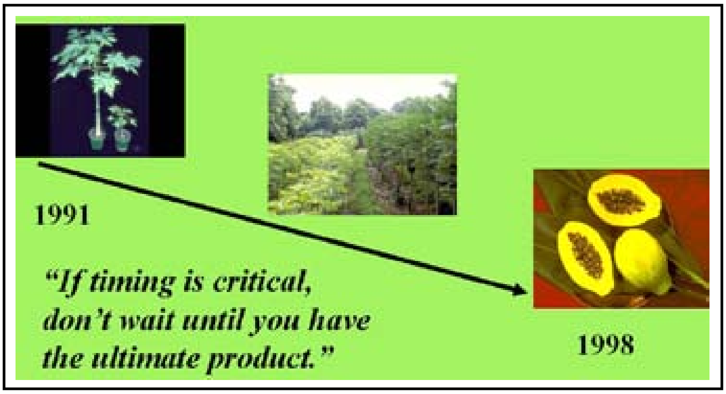


Figure 11. Under the best circumstances, it takes time.

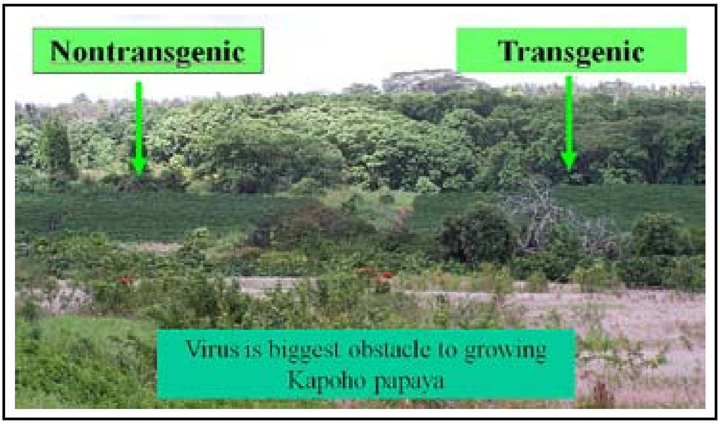


Figure 12. Coexistence under an identity-preservation protocol.

Deregulation Elsewhere

In Hawaii, we've been growing non-transgenic and transgenic papaya for more than a decade, because Japan, until recently, imported only non-transgenic papaya. This was achieved using identity-preservation protocols. Figure 12 shows a photograph taken in 2004, an example of the few fields where this applies. The most pressing problem isn't gene flow, it's loss of the non-transgenic crop due to the virus.

Deregulation in Canada was rapid because they acted on information from the United States. We started trying to deregulate the papaya in Japan a year after it was commercialized in the United States in 1998; it's a long story, but in December 2011 it was deregulated.

There is a common misperception that the Japanese consumer would be reluctant to buy it because it was labeled as being genetically modified. We went there expecting that with the first shipment of papaya, which was sold at Costco Japan. The most prevalent questions were, "How expensive is it?" and "Does it taste okay?" The Flavr Savr™ tomato failed not because it was genetically modified, but because it was unpopular. If you have a good product, consumers will buy it.

Addressing the Continuing Threat

In 2001, I said, "Don't forget the past," and Figure 13 contrasts the papaya situation then with how it had been in 1994. This is particularly appropriate now because a bill was recently introduced by a councilwoman on the big island in the county of Hawaii to ban all GMOs on the island of Hawaii where nearly all of the papaya is grown. The GM papaya would be "grandfathered" in, but would be grown under BSL-3 conditions. That bill was voted down. On July 2nd they changed the wording to require a 750-ft buffer zone

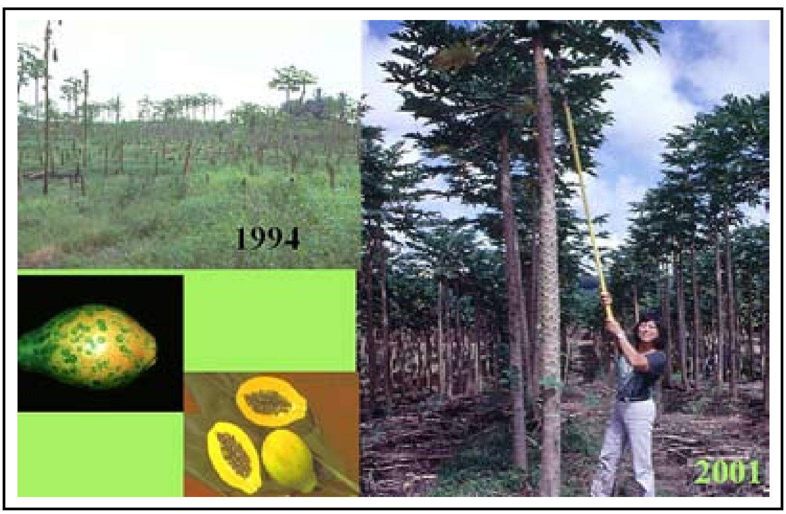


Figure 13. Don't forget the past.

between transgenic and non-transgenic papaya, which farmers are unhappy about. Now that I'm retired and a private citizen, I say that enough is enough. Papaya is the cheapest, most nutritious fruit in Hawaii. Four may be purchased for only a dollar in a farmers' market in Hawaii. This is the message that consumers must get across to the politicians. Some 85% of papaya now grown in Hawaii is transgenic. It's reasonably priced, and it tastes good; it's better than non-transgenic papaya. Figure 14 shows why farmers avoid non-GM genotypes: PRSV is still a serious threat.

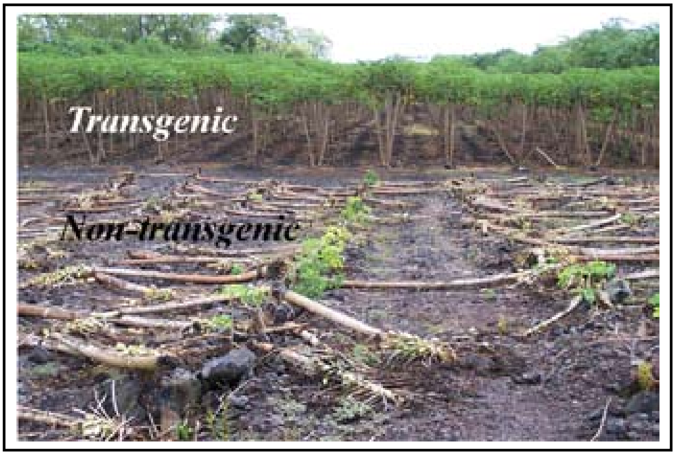


Figure 14. 2011—transgenic papaya at 85% of production.
PRSV remains a threat.

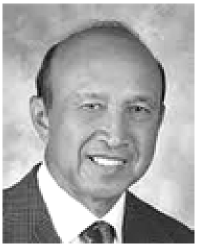
Figure 15. 1997—transgenic papaya brought to Thailand.

Thai Story: The Human Element

In 1994 we were asked to help tackle PRSV in Thailand. In our lab, Thai scientists developed locally adapted transgenic genotypes, which, in 1997, we hand-carried to Thailand. They worked beautifully in field trials. However, due to politics and lobbying of activists, our transgenic papaya will never be available to the Thai consumer and serious damage from the virus will continue to affect production and compromise the living standards of those who are most vulnerable (Figure 16).

In 2013, is transgenic papaya still a public-sector anomaly? Absolutely. We must continue our efforts in the red zone, dealing with people and with politics. We must bring the human element into the picture. What will the next 25 years bring? I hope it will not be the same old story.

Figure 16. Keep the human element in transgenic efforts.



DENNIS GONSALVES was born and raised on a sugar plantation in Hawaii. He was the director of the USDA Pacific Basin Agricultural Research Center in Hilo, Hawaii, from 2002 until his retirement at the end of 2012. He received his BS in horticulture (1965) and MS in plant pathology (1968) from the University of Hawaii, and his PhD in plant pathology (1972) from the University of California at Davis. He worked at the University of Florida from 1972 to 1977 and at Cornell University from 1977 to 2002, rising to the endowed position of Liberty Hyde Bailey professor in 1995.

Dr. Gonsalves does fundamental and applied research to control plant viruses. He was appointed to the Agriculture Research Service Science Hall of Fame in 2007 and received the Presidential Distinguished Rank Award in 2009. He led the team that developed—through the public sector—the virus-resistant transgenic papaya that saved the papaya industry in Hawaii. For this work, they received the Alexander Von Humbolt Award in 2002 for the most significant accomplishment in American agriculture in the previous five years.