

1 **REVISED May 5, 2020**

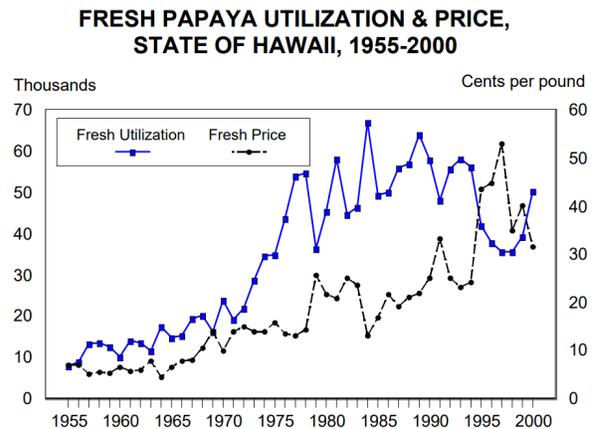
2 **Case Study: Eradication of Papaya Ringspot Virus on Hawaii: Agricultural Economist**

3 Papaya ringspot virus (PRV) is a major concern worldwide in papaya production because it is a  
4 disease that causes production of smaller, diseased fruit and smaller overall tree size. PRV is a  
5 disease that affects the whole papaya tree. PRV has been especially problematic in Hawaiian  
6 papaya production. While PRV was known to be present in Hawaii since the 1940's as a  
7 relatively mild viral infection, the virus mutated and became more aggressive in the 1950's  
8 leading to the Hawaii papaya industry almost being destroyed. While PRV was thought to be  
9 gone in 1975 from Hawaii, it resurfaced in the late 1990's.

10 Papaya trees that have the PRV disease grow less and have less fruit production which  
11 leads to less profits. This would suggest that as  
12 papaya trees become more sick with PRV, the  
13 cost of production will increase, but the amount  
14 of fruit produced will likely decrease (Figure 1).

15 **When PRV was widespread in Hawaii, the cost**  
16 of papaya increased for consumers before 1998  
17 when a solution was found. With the US being a  
18 large exporter of papaya, and most US produced  
19 papaya being grown in Hawaii, the impact of  
20 the disease was going to lead to a huge financial

21 loss for the industry. During the 1990s, there was a 50% decline in US papaya production due to  
22 this devastating virus. When the disease was at its worse, an average of 5,000 pounds of fruit per  
23 acre was produced, compared to the normal production size of 125,000 pounds of fruit per acre.



**Figure 1:** Price of Hawaii papaya (black) and the amount of papaya produced (blue). During the height of the PRV infection in the early 1990's papaya production decreased while price increased.

24 Scientists, agronomists, and farmers attempted various ways to decrease disease in  
25 Hawaiian papaya farms, such as removal of infected material, avoiding diseased fields, and aphid  
26 control but none of these solutions worked for long. To save the papaya industry in the US, the  
27 government allowed for genetically modified papaya to be produced. The genetically modified  
28 papaya, named Rainbow Papaya, although slightly different in color, is similar in flavor and size,  
29 giving customers the same experience. The price of papaya dropped by 22 cents/lb after the  
30 introduction of the genetically modified papaya, as Rainbow Papaya was able to produce more  
31 fruit per acre than the non-genetically modified papaya in light of PVR. Additionally, the  
32 genetically modified papaya is now being sold for 1 dollar at most Hawaiian farmer's markets.  
33 The average price for Hawaiian papayas in 2011 was approximately \$2.00/lb.

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48 **Case Study: Eradication of Papaya Ringspot Virus on Hawaii: Plant Pathologist**

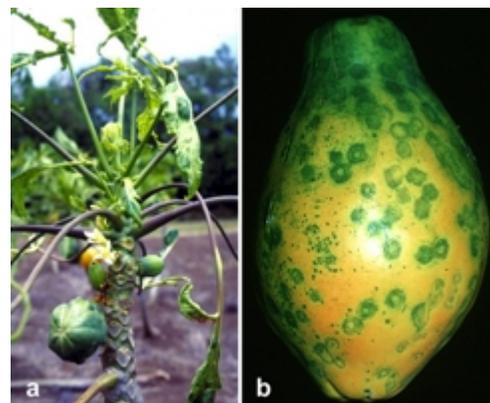
49 Papaya ringspot virus (PRV) is a major concern worldwide in papaya production because it is a  
50 disease that causes production of smaller, diseased fruit and smaller overall tree size. PRV is a  
51 disease that affects the whole papaya tree. PRV has been especially problematic in Hawaiian  
52 papaya production. While PRV was known to be present in Hawaii since the 1940's as a  
53 relatively mild viral infection, the virus mutated and became more aggressive in the 1950's  
54 leading to the Hawaii papaya industry almost being destroyed. While PRV was thought to be  
55 gone in 1975 from Hawaii, it resurfaced in the late 1990's.

56 PRV is a disease caused by a plant virus and is most common in tropical and subtropical  
57 environments. Specifically, PRV symptoms include wilted and spotted leaves and spotted fruits.

58 Symptoms vary based on stage of disease, but most commonly farmers will notice yellowing  
59 leaves, less growth, and spotted fruits (Figure 1). Leaf symptoms are more severe in cold  
60 temperatures. The virus is able to spread through the  
61 entire plant, thus if a plant is exhibiting PRV  
62 symptoms it is very hard to cure. The virus is spread  
63 by aphids, planting of infected seedlings, and by use  
64 of contaminated tools. The virus has not been shown  
65 to spread through the seeds.

66 PRV was first found in Hawaii in 1992 and  
67 quickly spread to take over the entire area in only  
68 five years. Scientists, agronomists, and farmers

69 attempted various ways to decrease disease in Hawaiian papaya farms, such as removal of  
70 infected material, avoiding diseased fields, and aphid control but none of these solutions worked



**Figure 1:** Papaya ringspot virus produces smaller and mis-shaped papayas that have rings on the outside.

71 for long. The only way to successfully get rid of the disease was by planting genetically  
72 engineered papaya that was resistant to PRV, meaning the virus was unable to infect these trees.  
73 A Hawaiian native research scientist, Dr. Gonsalves, got approval from the US Government to  
74 make and use the genetically engineered papaya called Rainbow Papaya. Farmers of Hawaiian  
75 papaya plantations began planting Rainbow Papaya in diseased fields and the resistance to the  
76 virus held strong. As a result, the Rainbow Papaya was widely adopted by the Hawaiian papaya  
77 farmers. Without the use of the Rainbow Papaya the Hawaiian papaya industry would have been  
78 lost.

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95 **Case Study: Eradication of Papaya Ringspot Virus on Hawaii: Agronomist**

96 Papaya ringspot virus (PRV) is a major concern worldwide in papaya production because it is a  
97 disease that causes production of smaller, diseased fruit and smaller overall tree size. PRV is a  
98 disease that affects the whole papaya tree. PRV has been especially problematic in Hawaiian  
99 papaya production. While PRV was known to be present in Hawaii since the 1940's as a  
100 relatively mild viral infection, the virus mutated and became more aggressive in the 1950's  
101 leading to the Hawaii papaya industry almost being destroyed. While PRV was thought to be  
102 gone in 1975 from Hawaii, it resurfaced in the late 1990's.

103 PRV results in much smaller plant and leaf size compared to a healthy plant. The  
104 decreased leaf size leads to lower fruit yield. In Hawaii, papaya is grown year-round. PRV is  
105 more infectious during the colder months, leading to less fruit  
106 production during cold month planted papaya. The disease is  
107 known to be spread by aphids, but using pesticides was  
108 useless in the height of the outbreak. Aphids are spread to  
109 papaya plants by strong wind, which is also required for  
110 papaya plant pollination. Scientists, agronomists, and farmers  
111 attempted various ways to decrease disease in Hawaiian  
112 papaya farms, such as avoiding specific growing areas and  
113 keeping plants to one specific location, but none of these  
114 solutions worked for long. There was not a good option to



**Figure 1:** Genetically modified Rainbow papaya (left) compared to a non-genetically modified papaya (right) after infection by PRV.

115 bring in a different variety of papaya because the papaya being grown had been bred to thrive in  
116 the high rainfall and volcanic, low nutrient soils of Hawaii. For most papaya varieties, too much  
117 water can cause root rot and ultimately death of the tree. However, the high rainfall in Hawaii,

118 mixed with the high drainage lava rock soils provide a perfect water regimen to the papaya bred  
119 for production on Hawaii.

120 To get rid of PRV on Hawaii, the government allowed for regulated production and use  
121 of genetically modified papaya that was resistant to PRV, known as Rainbow Papaya. Today,  
122 about 70% of papaya grown on Hawaii are Rainbow Papaya which has saved farmers  
123 livelihoods. The Rainbow papaya is much larger than an infected non-genetically modified  
124 papaya and therefore, can produce more papaya fruit (Figure 1). The use of the genetically  
125 modified plants alongside non-genetically modified papaya also help to increase the diversity of  
126 papaya in Hawaii which could help to protect more varieties if PRV is able to infect Hawaii  
127 papaya again. Concerns first associated with the use of genetically modified papaya have now  
128 lessened as the Hawaiian population has accepted the Rainbow Papaya due to the advantages it  
129 brought to the papaya industry.

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141 **Case Study: Eradication of Papaya Ringspot Virus on Hawaii: Climatologist**

142 Papaya ringspot virus (PRV) is a major concern worldwide in papaya production because it is a  
143 disease that causes production of smaller, diseased fruit and smaller overall tree size. PRV is a  
144 disease that affects the whole papaya tree. PRV has been especially problematic in Hawaiian  
145 papaya production. While PRV was known to be present in Hawaii since the 1940's as a  
146 relatively mild viral infection, the virus mutated and became more aggressive in the 1950's  
147 leading to the Hawaii papaya industry almost being destroyed. While PRV was thought to be  
148 gone in 1975 from Hawaii, it resurfaced in the late 1990's.

149 PRV results in less papaya growth and fruit  
150 production. Symptoms of the disease include spots on the  
151 leaves, stem and fruit. The fruit may also be distorted in  
152 shape. Once infected with the virus, the plant cannot  
153 recover, and papaya plantations become decimated



**Figure 1:** Hawaiian papaya field devastated by the Papaya ringspot virus.

154 (Figure 1). In Hawaii, papaya is grown year-round. PRV  
155 is more infectious during the colder months, leading to  
156 less fruit production during cold month planted papaya. While the disease is less infectious  
157 during warm months, the papaya can stop producing fruit during warm weather and decrease  
158 yield. Thus, changing the growing season was not a good option. The disease is spread by aphids  
159 which do not normally choose to feed on papaya, but if other plants that aphids do feed on, such  
160 as melon, are in the same field, an aphid infestation in papaya is possible. Aphids are not flying  
161 organisms so they would slowly infect other plants. However, in the presence of high wind,  
162 aphids can easily be carried to new plants to infect.

163           Scientists, agronomists, and farmers attempted various ways to decrease disease in  
164 Hawaiian papaya farms, such as avoiding specific growing areas and keeping plants to one  
165 specific location, but none of these solutions worked for long. There was not a good option to  
166 bring in a different variety of papaya because the papaya being grown had been bred to thrive in  
167 the volcanic, low nutrient soils of Hawaii. Because the wind and growing season temperatures  
168 helped to increase the prevalence of the disease, PRV moved too quickly to determine which  
169 plant would be susceptible to the virus infection. To get rid of PRV, the government allowed for  
170 regulated production and use of genetically modified papaya that contained a gene for resistance  
171 to the PRV, known as Rainbow Papaya. Rainbow Papaya is now thriving in the Hawaiian papaya  
172 production, making up 70% of the market.

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222 [savior-blazes-biotech-trail-but-few-sci-88379.html?pagewanted=all](https://archive.nytimes.com/www.nytimes.com/gwire/2011/09/21/21greenwire-crop-savior-blazes-biotech-trail-but-few-sci-88379.html?pagewanted=all)

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