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RESEARCH ARTICLE

ECONOMIC BENEFIT FROM ADOPTION OF GM PAPAYA: AN EX-ANTE EVALUATION

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ABSTRACT

Currently, papaya production in South Florida is significantly limited as a result of the papaya ring spot virus. Successful resistance in other countries evidences the potential of GM technology to impact the US domestic papaya economy. In assessing the viability of this solution, we examine the economic benefit in scenarios of GM papaya adoption with varying adoption rates and production areas using an economic surplus method. Estimated total economic surplus generated within the first five years of adoption ranged from USD 13.20 million to USD 37.47 million, with the majority of benefit being received by small-scale producers.

Key Words: Economic Surplus, Florida, GM Papaya, PRSV, Papaya Ring Spot Virus

INTRODUCTION

The papaya ring spot virus (PRSV) is a major economic issue in Florida. Yield reduction due to PRSV has been known to reach 80% in environmentally similar areas such as the Philippines (Yorobe, 2009).A lack of supply of papaya could result in greater imports from South America, further increasing the existing trade imbalance. Gonsalves (1998) studied the impact of PRSV in Hawaii and found that cross protection failed to completely protect from PRSV symptoms. This study found that the development of GM papaya with a parasite-derived resistance was an economically viable method of controlling PRSV. In 1999, Rainbow, a GM papaya developed to control the Hawaiian isolate of PRSV, proved to be very successful in recovering yields and production area (Gonsalves *et al*., 2004). To combat PRSV in Florida, the University of Florida is developing a GM papaya, which is awaiting approval from the EPA. Despite the global success of GM adoption, Florida growers remain somewhat skeptical about GM papaya. For example, a recent survey undertaken by the University of Florida to determine the willingness of growers to produce a GM papaya variety found that 60% of the respondents were willing, but 40% had concerns related to environmental and health issues. Currently, the search for alternative commodities in Florida becomes increasingly important as major crops such as citrus fall in production due to greening disease (Chung and Brlansky, 2005). This study analyzes the potential economic benefit of adopting GM papaya in South Florida.

Background

Genetically modified (GM) papayas have been the subject of many similar economic evaluations. These studies generally focus on the net exporters of papaya.

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Hawaii, the largest US exporter of papaya, experienced high rates of adoption of the PRSV-resistant papaya, Rainbow. From May 1998 to September 1999, 80% of farmers who had received the GM seeds planted them within the first three months, indicating a relatively high and fast adoption rate (Gonsalves *et al*., 2004). Sankula *et al*. (2005) found that with increased Rainbow adoption, per acre papaya yield increased 7% from 2003 to 2004, and resulting crop production increased by 11.8 million pounds, with a value of $4.4 million. Between 1999 and 2003, seed technology was provided at no cost, but subsequently increased to $32/acre in 2004. When accounting for adoption costs, PRSV-resistant papaya was estimated to have increased economic benefit by $19.7 million from 1999 to 2004.

Napasintuwong and Traxler (2009) evaluated the ex-ante impact of GM papaya in Thailand using an economic surplus model. They used a small open economy (allowing for exports) in addition to a closed economy framework to account for the possibility that the GM papaya would not be accepted in export markets. They assumed that there would be no cost savings because the current papaya growers did not use pesticides or herbicides. Over a thirteen-year period, they found that producer surplus would increase by 35.3 billion baht (Thailand currency) (equivlanet to USD 1.04 billion) in an open exporting economy based on the 2002–2006 production area. When assuming that GM papaya would result in an expanding production area equal to pre-PRSV levels, they found that the producer surplus would increase by 50.2 billion baht (USD 1.48 billion).

Moreover, their results indicated that under the open economy framework, producers captured all of the benefits due to a combination of reduction in unit cost and increase in yield. Under the closed model assumption, the said authors found that both consumers and producers received benefits.

The total economic surplus was estimated at 22.2 billion baht (USD 0.65 billion) under the 2002–2006 production area, with 14.8 billion baht toward consumer surplus and 7.4 billion baht toward producer surplus. They estimated total economic surplus would be 27.6 billion baht (USD 0.81 billion) under the expanding production area, with 18.4 billion baht toward consumer surplus and 9.2 billion baht toward producer surplus. Gonsalves *et al*. (2007) found that the development of GM papaya would mainly benefit smaller farmers who cannot afford other means of virus protection. There were no economies of scale from investment in large amounts of capital or excessive variable production costs regarding PRSV-resistant papaya. Thus, the barriers to adoption for small-scale farmers were mitigated. In an ex ante assessment of the socioeconomic impact of GM papaya in Mexico, Silva-Rosales *et al*. (2010) found PRSV to act as a natural barrier to entry in papaya production. Their study suggested that large producers are able to adapt farming practices and management of non-GM papaya to mitigate the effects of PRSV. However, smaller farmers were discouraged from entering the papaya agribusiness due to high production costs. They found that while GM papaya would provide a solution to high production costs and reductions in crop yields, small-scale farmers lack the political power to promote the transfer and adoption of GM papaya.

Davis and Ying (2004) examined PRSV isolates from South Florida and found a genetic similarity to isolates from Puerto Rico and Mexico. They indicated that a PRSV-resistant papaya based on the Florida isolate could also have an effect on the Caribbean region. Additionally, Gonsalves (1998) came up with an interesting finding which suggested that GM papaya supported the production of non-GM papaya by reducing the amount of available virus inoculum and infected areas. By using GM papaya plants as a physical buffer from aphid vectors, non-GM farmers were able to reduce virus pressure on non-GM papaya plants. Aphids that feed on GM papaya are rendered innocuous while the increase in physical distance from non-GM plants also reduces the chance of infection. Elimination of infected trees in coordination with buffering using GM papaya plants has proven successful in the production of non-GM papaya for particular export markets.

Theoretical Framework

The economic impact of the adoption of GM papaya is estimated using an economic surplus model. The advantage of the surplus model is that it takes into account different types of markets, research-induced changes, and various supply and demand elasticities (Alston *et al*., 1998). With the proper assumptions of market factors, benefits can be found and disaggregated into consumer and producer components. Due to lack of information on the relationship between sectors, we use a partial equilibrium model. The vast majority of papaya produced in Florida is consumed domestically. Papaya is also imported due to insufficient domestic production. It is assumed that Florida is a net importer of papaya and operates as a small importing economy because imports to Florida are less than 1% of world imports. This domestic market is assumed to be homogeneous because the United States does not require GM labeling (Gruère *et al*., 2007). Figure 1 shows the change in economic surplus as a result of adoption of GM papaya.

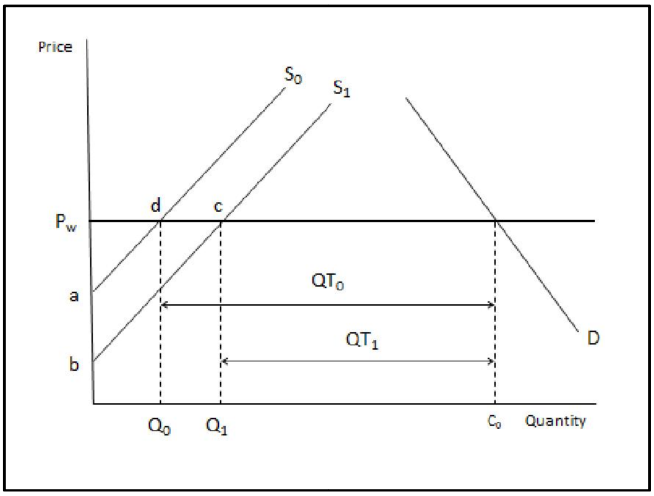

Figure 1. Economic surplus from adoption of GM papaya

The supply curve shifts downward from S_0 to S_1 as a result of the change in technology. The demand curve of papayas is unaffected. As a result, producer surplus increases by the area $abcd$, while consumer surplus remains constant. As a small importing economy, Florida is a price taker. The world price at P_w determines the price of papaya and is unaffected by the increase in supply in Florida. The increase in supply leads Floridato decrease its imports from QT_0 to QT_1.The benefits to the local growers can therefore be captured by estimating the increase in consumer surplus represented by area $abcd$.

MATERIALS AND METHODS

Dynamic Research Evaluation for Management (DREAM) software is used to measure the change in economic surplus. This ex-ante model is based on concepts taken from Alston *et al*. (1998). The technology-induced shift in the supply curve, K, can be found as a change in the intercept;

$$K_t = \left[\frac{\Delta Y}{\varepsilon} - \frac{\Delta C}{1+\Delta Y}\right] pA_t(1-\delta_t), \quad \text{.............................. (1)}$$

where K_t is theproportionate shift in the supply curve in year t due to GM papaya adoption, ΔY is the expected proportionate change in yield per ha, ΔC is the expected proportionate change in variable cost per ha, p is the probability that GM papaya will achieve the expected yield, A_t is the adoption rate, the proportionate area of GM papaya to total papaya production area in year t, and δ_t is expected reduction of depreciation of GM papaya (reduction of expected yield) in year t.

The following equation was used to find the producer surplus in a small open economy,

$$\Delta TS_t = \Delta PS_t = P_w Q_0 K_t (1 + 0.5 K_t \varepsilon), \quad \text{...................... (2)}$$

where ΔTS_t is the change in total surplus in year t, ΔPS_t is the change in producer surplus in year t, P_w is the world price, Q_0 is the production of papaya, K_t is the proportional supply shift in year t, and ε is the supply elasticity; In this model, we assumed that after an initial research lag of three years, the impacts of the adoption accrue for five years. The net present value (NPV) is calculated by discounting the change in economic surplus each year using a discount rate equivalent to the real interest rate. The following equation was used:

$$\text{NPV} = \sum_{t=0}^{T} \frac{\Delta TS_t}{(1+r)^t}, \quad (3)$$

where r is the discount factor.

The following four scenarios are calculated using the described method:

- Current production area with 64% adoption rate
- Area expansion to pre-PRSV infestation levels with 64% adoption rate
- Current production area with 90% adoption rate
- Area expansion to pre-PRSV infestation levels with 90% adoption rate

Assumptions

Assumptions werebased on economic data in Florida and supplemented with relevant information from similar economic studies in other countries. The parameters assumed in the small importer economy are shown in Table 1.

depreciation observed in the commercialization of GM crops, this study also assumes depreciation is zero. The expected yield improvement is assumed to be 239% as the potential yield of GM papaya is 95 tons/ha (Migliaccio *et al*. 2010) and the average yield of current papaya production is assumed to be 25.22 tons/ha (Crane 2009).

The current production of papaya is estimated at 3,062 tons and is assumed for the initial period in all scenarios. In Scenarios 1 and 3, the total area planted to papaya is assumed to remain at the current level of 121 hectares. Gonsalves (2006) found that GM papaya resulted in an increase in production area, allowing for planting in previously PRSV-infested areas. In accounting for maximum adoption area, Scenarios2 and 4 assume total area planted to increase from 121 to 202hectares, a compound annual growth rate of 10.76%.

Evans et al. (2012) assumed an average freight on board market price for papaya in Florida of USD 882/ton based on interviews with growers. The US Food Market Estimator (2014) found current consumption level to be approximately 3,717 tons, which was used to calculate import volume. Based on assumptions by Bayer *et al*. (2010) and Napasintuwong and Traxler (2009), the price elasticity of supply is assumed to be 0.8.

Table 1. Model scenario assumptions

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Production Quantity, Q_0 (ton)	3,062	3,062	3,062	3,062
Price, P_0 (dollar/ton)	882	882	882	882
Non-GM yield (ton/ha)	25.22	25.22	25.22	25.22
GM yield (ton/ha)	95	95	95	95
Yield increase, $\Delta \boldsymbol{Y}$	277%	277%	277%	277%
Cost change, $\Delta \boldsymbol{C}$	20%	20%	20%	20%
Production area (ha)	121	202	121	202
Annual growth in production area	0.00%	4.01%	0.00%	4.01%
Maximum adoption rate	64%	64%	90%	90%
R&D lag (years)	3	3	3	3
Adoption lag (years)	5	5	5	5
Probability of achieving yield	90%	90%	90%	90%
Import volume, C_0-Q_0 (ton)	655	655	655	655
Consumption quantity, C_0 (ton)	3,717	3,717	3,717	3,717
Supply elasticity	0.8	0.8	0.8	0.8
Demand elasticity	∞	∞	∞	∞

Table 2. Economic benefit in 1000 USD

Year	Scenario 1			Scenario 2			Scenario 3			Scenario 4		
	ΔPS	ΔCS	ΔTS	ΔPS	ΔCS	ΔTS	ΔPS	ΔCS	ΔTS	ΔPS	ΔCS	ΔTS
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	175.0	0	175.0	237.2	0	237.2	248.5	0	248.5	336.6	0	336.6
2018	1,098.4	0	1,098.4	1633.1	0	1633.1	1,622.9	0	1,622.9	2402.9	0	2402.9
2019	4,070.2	0	4,070.2	6588.5	0	6588.5	6,415.7	0	6,415.7	10306.5	0	10306.5
2020	6,339.4	0	6,339.4	11282.1	0	11282.1	10,259.7	0	10,259.7	18107.2	0	18107.2
2021	6,867.9	0	6,867.9	13519.1	0	13519.1	11,168.5	0	11,168.5	21800.1	0	21800.1
NPV	13,195.6	0	13,195.6	23559.4	0	23559.4	21,114.2	0	21,114.2	37474.1	0	37474.1

A three-year R and D lag to initial adoption is assumed because the University of Florida has finished the development of its PRSV GM papaya varieties but continues to work with the EPA to register them as plant incorporated pesticide. While Napasintuwong and Traxler (2009) assumed the probability of achieving expected yield to be 100%, Yorobe (2006) assumed a lower probability of 83% while both studies assumed a discount factor of 5%. Thus, we assume a probability of 90% and a discount factor of 5%. Since there has been no

As further evidence, the production of papaya does not require a large component of fixed inputs and there is a limited amount of land to papaya production in Florida. De Oleo (2014) found that 64% of farmers in South Florida are willing to adopt GM papaya. Of the farmers who were unwilling to grow GM papaya, the main reasons cited were concern over health risks and market acceptance. Although Napasintuwong and Traxler (2009) and Bayer *et al* (2010) assumed 80% adoption rate in Thailand and the Philippines, this study assumes a more conservative adoption rate due to the lesser degree of importance of papaya in Florida agriculture. Based on these studies and farmer surveys, this study assumes a maximum adoption rate of 64% within five years in Scenarios 1 and 2. A higher adoption rate of 90% is assumed in Scenarios 3 and 4under the assumption that research and extension of the safety of GM papaya consumption proves beneficial. The higher adoption rate also assumes market acceptance increases over time such as with the acceptance of GM papaya in Japan in 2011 (USDA/FAS 2011). The adoption of GM papaya was assumed to be in a sigmoid form. According to Yorobe (2009), with the adoption of GM papaya, the costs of production and marketing will increase. A premium on GM seeds, increased irrigation and fertilization,and greater demand for papaya care and harvesting will contribute to the expected rise.A total cost increase of 20% is estimated in the adoption of GM technology. No cost savings are assumed as no changes in susceptibility to pests and diseases other than PRSV were observed (Davis 2008). This study does not take into account the cost of research and development of GM papaya due to a lack of information.

RESULTS

Table 2 shows the estimates of economic surpluses made using DREAM. Under small importing economy scenarios, the increase in total surplus is received only by producers. Producers will benefit from the large improvement in yield and thus unit-cost reduction. Consumer surplus remains constant since world price and demand do not change as a result of GM papaya. Consumers receive intangible benefits in the form of increased stability and quality of papaya consumption. When accounting for a greater adoption area, benefits are greater as well. When the total production area is assumed at the current level in Scenario 1 and adoption rate is at 64%, the total discounted value of economic surplus from years 2014 to 2021 is USD 13.20 million. If the production area grows at 10.76% per year to reach pre-PRSV levels while the adoption rate remains constant, the NPV of GM papaya adoption (the impact of adoption of the new technology) is USD 23.56 million as shown in Scenario 2. With a greater adoption rate, the benefits received from an increase in production area are even more notable.

At the current level of production area and 90% adoption rate, from years 2014 to 2021 NPV is USD 21.11 million. At the expanded level of production area and 90% adoption rate, NPV increases significantly to USD 37.47 million. If GM papayas are adopted on a global scale, producer surplus will increase significantly due to improvement in yields while consumer surplus will benefit from a decrease in world price. Total economic surplus will rise, as the fall in market price is more than offset by the increase in productivity.The increase in adoption rate from 64% to 90% resulted in a large increase in economic benefit (Scenarios 1 and 3 to Scenarios 2 and 4). While there is no change in consumer surplus, NPV of GM papaya adoption in Scenario 3 isUSD 21.11 million, which is a 60% increase in benefit when compared to Scenario 1. In Scenario 4, the NPV when taking area growth into account is USD 26.30 million, which represents an increase of 60% from Scenario 2.

Conclusions

The papaya industry in Florida has been depressed by PRSV, with current production a fraction of past figures. Historically, GM papaya developed in countries afflicted by PRSV has proven economically successful. GM papaya varieties have been developed by the University of Florida but still await approval from the EPA for tolerance exemption. Although the PRSV coat protein gene has already been approved in Hawaii, delays in the registration of the Florida gene can prove costly. Farmer surveys suggest that once GM varieties are made commercially available, the majority of papaya planters would be willing to adopt the technology. However, a percentage of planters still express concern over health risks and market acceptance of GM papaya. Extension and education programs on GM papaya will be necessary to change the perception of farmers and consequently raise adoption of GM technology and economic surplus. With a successful adoption of GM papaya, small-scale farmers impacted by PRSV will receive the greatest proportion of benefit. Although consumer surplus does not change in the small importing economy model, it still receives benefit in the form of stability and quality of papaya consumption. GM papaya may also provide South Florida farmers with an alternative commodity to current crops greatly affected by diseases. The information presented in this evaluation provides strong economic evidence for the benefit Florida could gain from. GM papaya.

REFERENCES

Alston, J.M., Norton, G.W. and Pardey, P.G. 1998. *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*. Ithaca: Cornell University Press.

Bayer, J.C., Norton, G.W. and Falck-Zepeda, J. 2010. Cost of compliance with biotechnology regulation in the Philippines: Implications for developing countries. *AgBioForum*, 13(1), Article 4. http://www.agbioforum.org/v13n1/v13n1a04-norton.htm

Chung, K.R. and Brlansky R.H. 2005. Citrus diseases exotic to Florida: Huanglongbing (citrus greening). EDIS #PP133. UF/IFAS Extension, Gainesville, FL. http://edis.ifas.ufl.edu / PP133.

Crane, J.H. and Mossler, M.A. 2009. Florida crop/pest management profile: Papaya.EDIS #PI053 (CIR1402). UF/IFAS Extension, Gainesville, FL. http://edis.ifas.ufl.edu/pi053.

Davis, M. 2008. University of Florida petition 04-337-01P seeking a determination of nonregulated status for X17-2 papaya resistant to papaya ringspot virus. USDA/APHIS, Washington, D.C. http://www.regulations.gov/fdmspublic/component/main?main=DocumentDetail&o=09000064806cf5de.

Davis, M.J. and Ying, Z. 2004. Development of papaya breeding lines with transgenic resistance to papaya ringspot virus. *Plant Disease*, 88 (4), 352-358.

De Oleo, B., Evans, E. and Crane, J.H. 2014. Willingness to grow GM papaya in South Florida: GMO myths debunked. Online University of Florida lecture conducted from Homestead, Florida.

Evans, E.A., Ballen, F.H. and Crane, J.H. 2012. 2012 Cost estimates of establishing and producing papaya (Carica papaya) in South Florida. Electronic Data Information Source (EDIS) FE918, University of Florida, Gainesville,

Gonsalves, C., Lee, D.R. and Gonsalves, D. 2007. The adoption of genetically modified papaya in Hawaii and its implications for developing countries 1. *Journal of Development Studies*, 43, 177-191.

Gonsalves, C., Lee, D.R. and Gonsalves, D. 2004. Transgenic virus-resistant papaya: the Hawaiian 'Rainbow'was rapidly adopted by farmers and is of major importance in Hawaii today. *APSnet Feature*.http://www.apsnet.org/publications/apsnetfeatures/Pages/PapayaHawaiianRainbow.aspx

Gonsalves, D. 1998. Control of papaya ringspot virus in papaya: A case study. *Phytopathology*, 36, 415-437.

Gonsalves, D. 2006. Transgenic papaya: Development, release, impact and Challenges. *Advances in Virus Research*, 67, 317-354.

Gruère, G.P., Carter, C.A. and Farzin, Y.H. 2009. Explaining international differences in genetically modified food labeling policies. *Review of International Economics*, 17, 393-408.

Migliaccio, K.W., Schaffer, B., Crane, J.H. and Davies, F.S. 2010. Plant response to evapotranspiration and soil water sensor irrigation scheduling methods for papaya production in south Florida. *Agricultural Water Management*, 97, 1452-1460.

Napasintuwong, O. and Traxler, G. 2009. Ex-ante impact assessment of GM papaya adoption in Thailand. *AgBioForum*, 12, 209-217.

Sankula, S., Marmon, G. and Blumenthal, E. 2005. *Biotechnology-derived Crops Planted in 2004: Impacts on US Agriculture*. Washington DC: National Center for Food and Agricultural Policy.

Silva-Rosales, L., González-de-León, D., Guzmán-González, S. and Chauvet, M. 2010. Why there is no transgenic papaya in Mexico. *Transgenic Plant Journal*, 4(Special Issue 1), 45-51.

US Food Market Estimator (2014) http://www.ctre.iastate.edu/marketsize/ Accessed November 2014

USDA/FAS 2011. *Japan Approved GM Papaya*. (Report No. JA1048). United States Department of Agriculture, Foreign Agricultural Service, Washington, D.C. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Japan%20approved%20GM%20papaya_Tokyo_Japan_12-19-2011.pdf. (Accessed 10 August 2014)

Yorobe, J. 2009. Costs and benefits of bioengineered papaya with resistance to papaya ringspot virus in the Philippines. In G.W. Norton & D.M. Hautea (Eds.), *Projected Impacts of Agricultural Biotechnologies for Fruits & Vegetables in the Philippines & Indonesia*. Los Baños, Philippines: ISAAA.

Yorobe, J.M. Jr. 2006. *Ex Ante Economic Impact Assessment of the Ring Spot Virus Resistant Papaya in the Philippines*. Los Baños, Philippines: ISAAA.

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