"Enseñar la explotación de la tierra, no la del hombre"

UNIVERSIDAD AUTÓNOMA CHAPINGO

CENTRO DE INVESTIGACIONES ECONÓMICAS, SOCIALES Y TECNOLÓGICAS DE LA AGROINDUSTRIA Y LA AGRICULTURA MUNDIAL
CIESTAAM

ANÁLISIS DE ACCIONES DE POLÍTICA PÚBLICA APLICADA CONTRA HUANGLONGBING (HLB) EN LIMÓN

TESIS

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PRESENTA

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Análisis de acciones de política pública aplicada contra Huanglongbing (HLB) en limón

Tesis realizada por María Elena Vera Villagrán, bajo la dirección del Comité asesor indicado, aprobada por el mismo y aceptada como requisito parcial para obtener el grado de

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“No pretendamos que las cosas cambien, si siempre hacemos lo mismo. La crisis es la mejor bendición que puede sucederle a personas y países, porque la crisis trae progresos. La creatividad nace de la angustia como el día nace de la noche oscura. Es en la crisis que nace la inventiva, los descubrimientos y las grandes estrategias. Quien supera la crisis se supera a sí mismo sin quedar 'superado'. Quien atribuye a la crisis sus fracasos y penurias, violenta su propio talento y respeta más a los problemas que a las soluciones. La verdadera crisis, es la crisis de la incompetencia. El inconveniente de las personas y los países es la pereza para encontrar las salidas y soluciones. Sin crisis no hay desafíos, sin desafíos la vida es una rutina, una lenta agonía. Sin crisis no hay méritos. Es en la crisis donde aflora lo mejor de cada uno, porque sin crisis todo viento es caricia. Hablar de crisis es promoverla, y callar en la crisis es exaltar el conformismo. En vez de esto, trabajemos duro. Acabemos de una vez con la única crisis amenazadora, que es la tragedia de no querer luchar por superarla”: Albert Einstein

DATOS BIOGRÁFICOS

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✓ Subsecretaría de Fomento a los Agronegocios de la Secretaria de Agricultura , Desarrollo Rural, Pesca y Alimentación (SAGARPA)

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✓ Fomento de Ingeniería, S.A. de C.V.

Coordinadora a cargo de estudios para caracterizar áreas o zonas en riesgo de ser afectadas por impacto ambiental de actividades agroindustriales.

PRESENTACIÓN

El presente trabajo de investigación se diseñó en la modalidad de artículos y surge de la interacción que en 2007 la autora tuvo con el sector citrícola derivado de sus actividades dentro de la Subsecretaría de Fomento a los Agronegocios de SAGARPA. La SFA buscaba poner a disposición de los tomadores de decisiones del sector, información de carácter económico que permitiera hacer una serie de mejoras productivas. Por lo anterior, productos estratégicos para el país fueron investigados.

El limón mexicano fue elegido por el rápido crecimiento en las exportaciones mostrado por más de una década (desde 1990), por haber superado barreras fitosanitarias internacionales en los últimos diez años y por que se perfilaba para competir con muy buenas posibilidades en el mercado estadounidense. Sin embargo, las alertas fitosanitarias se habían activado en Brasil. El Huanglongbing (HLB), la enfermedad más devastadora en cítricos había llegado a ese país en el 2004. Para el 2005, ya se encontraba en Florida, Belice y Cuba. Se esperaba una afectación severa en naranja, por lo que en 2008, en México se advirtió del HLB mediante una campaña de concientización, especialmente dirigida a los naranjeros, en la cual se especificaban los riesgos de la enfermedad.

En nuestro país el HLB apareció a finales del 2009 en Yucatán y en 2010 en Colima, primer productor de limón mexicano. La dispersión de la enfermedad fue muy rápida. La autora tuvo la oportunidad de visitar el estado y entrevistar a los productores afectados, que se veían en una clara negación de la situación que se estaba viviendo.

El SENASICA, encargado de las campañas de control inició inmediatamente la cuarentena y la emisión de las normas, protocolos y acuerdos preparados para enfrentar la amenaza. Sin embargo, la respuesta de gran parte de los citricultores era muy baja o incluso negativa.

En información recabada por la autora, algunos citricultores manifestaban que su plan era usar una mayor cantidad de fertilizantes porque el aspecto de los árboles era el típico de deficiencias nutricionales. Sin embargo, SENASICA manifestó que no era la forma adecuada de manejar esta enfermedad. Con estas observaciones, la autora desarrolló el trabajo de oferta y demanda de limón en México y Estados Unidos usando variables clave que pusieran en evidencia cómo una decisión de política pública puede afectar tanto la oferta como la demanda de un producto de la importancia del limón.

Al continuar con la investigación, se cuestionaba a los productores si los costos de producción se habían incrementado por la presencia de la enfermedad, a lo que respondieron afirmativamente, lo anterio debido a un mayor uso de fertilizantes.

Un gran porcentaje de los productores tuvo apoyo para la aplicación de insecticidas por parte de SAGARPA. Pero aún con este apoyo, para el año 2012 en Colima, se observó un decremento en los ingresos, debido a la reducción en el rendimiento de todos los árboles sintomáticos. Lo anterior porque gran parte de los citricultores no permitieron la erradicación de los árboles sintomáticos, se aplicaba sólo el insecticida proveído por el gobierno federal y no se replantaron plantas certificadas libres de HLB.

De estas observaciones, la autora propuso calcular el beneficio y el costo de la aplicación de la estrategia de los tres componentes como se hizo en Brasil; esto es, que todos los costos corren por cuenta del productor. Brasil por medio de Fundecitrus reportaba muy buenos resultados sobre el control de la enfermedad lo que permitió hacer una visita a este país y conocer directamente a los investigadores a cargo de hacer funcionar la estrategia.

Por otro lado en Florida, Estados Unidos, se promovió el uso de fertilizantes y fortalecedores de los sistemas inmunes de los árboles por parte de los mismos citricultores, lo anterior a pesar de que expertos de las agencias a cargo del control de plagas y enfermedades en este país (APHIS y ARS) aconsejaron no realizar estas aplicaciones. Esto también pudo ser observado y cuestionado directamente en el lugar, y de aquí, se elaboró el modelo para calcular el uso de variedades mejoradas y vacunas que podría ser usado de manera preventiva en Veracruz. En el momento que se planeó este modelo, se asumía una infección inminente, por lo que ésta podría ser la forma en que los productores de limón persa mantendrían la producción y las exportaciones sin una afectación drástica.

Por lo expuesto anteriormente, el presente trabajo está fundamentado en las observaciones directas al visitar las huertas citrícolas, en la consulta de la bibliografía disponible sobre el tema del HLB y en el planteamiento de la factibilidad de la adopción de estas acciones de política pública elegidas por los citricultores.

Análisis de acciones de política pública aplicada contra Huanglongbing (HLB) en limón
Assessment of public policy actions applied to Huanglongbing control on lime

María Elena Vera Villagrán.[1], y Leticia Myriam Sagarnaga Villegas.[2]

RESUMEN

El Huanglongbing (HLB) es una enfermedad en cítricos que se ha esparcido mundialmente e impactado la producción de manera adversa en el último siglo. En México, el HLB apareció en Colima, principal productor de limón mexicano, en abril de 2010 y se esparció rápidamente en todo el estado a pesar de los esfuerzos por controlarla por parte del gobierno federal y de productores que se involucraron en la campaña. La estrategia federal para el manejo y control de esta enfermedad tiene su fundamento en recomendaciones internacionales aplicadas en China, Brasil y Estados Unidos. Estas acciones consisten en A) Erradicar árboles sintomáticos, B) Replantar con árboles de viveros certificados que garanticen que están libres de HLB y C) Controlar la población del psílido asiático de los cítricos (PAC), vector del HLB. Esta tesis documenta como la llegada del HLB representa un reto para los citricultores y su decisión de apegarse a una campaña federal de control y manejo. Este trabajo está integrado por tres artículos. Primero se inicia con un análisis de oferta y demanda de limón en México y su exportación a Estados Unidos donde se encontró que la primera decisión sobre la aplicación extra de fertilizantes ante la amenaza del HLB afecta las variables de la oferta y la demanda como precio de limón mexicano, precio de limón persa, y precio de fertilizantes. Segundo- se toma como referencia la experiencia en Brasil en el manejo del HLB, con lo que se encontró el beneficio-costo de la aplicación de la estrategia de los tres componentes en el Estado de Colima. Tercero- se cuantificaron los costos de adoptar variedades resistentes y vacunación usando Unidades Representativas de Producción (URPs), encontrándose que su viabilidad general depende del acompañamiento en la aplicación de las mismas. Finalmente, se integran las posibles implicaciones y opciones de las estrategias consideradas para lidiar con el HLB.

Palabras clave: HLB, Limón, política pública, oferta- demanda, beneficio- costo.

ABSTRACT

Huanglongbing (HLB) is a worlwide citrus disease that has spread and affected production adversely during the last century. HLB was first found in April 2010 in the Mexican State of Colima, main key lime producer, and spread rapidly throughout the whole state in spite of efforts to contain it by the federal government and producers involved in the campaign. The federal strategy is based on the international recommended actions applied in China, Brazil, and the U.S. These actions are A) Eradication of symptomatic trees, B) Replanting with certified greenhouse trees that are guaranteed being free of HLB and C) Controlling the HLB vector, (Asian citrus psyllid population ACP). This thesis documents how the arrival of HLB represents a challenge to citrus growers and their decision to stick to a federal campaign about management and control. Three scientific articles compose this document. First, the analysis of lime demand and supply in Mexico and its exports to the United States of America. Results found that the initial decision taken by the citrus growers against HLB, which is applying higher quantities of fertilizers, affects supply and demand variables such as key lime price, Persian lime price and fertilizers price. The second article takes examples from citrus growers in Brazil; therefore, it was found that the benefit-cost ratio obtained for the application of the three actions' strategy is economically feasible. The third document is about radical changes in the management of citrus orchards using Represetative Production Units (URPs). This is adopting vaccines and resistant citrus trees varieties. It was found that the adoption of these strategies and their general viability depends on the accompanying counseling given to producers. Finally, the appraisal of possible implications and public policy options that the considered strategies give to citrus growers to deal with HLB are included.

Key words: HLB, Lime, public policy, supply-demand, benefit- cost.

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[1] Estudiante .

[2] Directora

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Capítulo I

I.1. Introducción general

El propósito de este documento es brindar información para establecer la importancia de la producción de limón en México, en particular en Colima, y analizar los factores que contribuyen a la respuesta de los actores directamente involucrados en la producción de este cítrico, ante una crisis fitosanitaria.

La producción de limón es una actividad socioeconómica de gran importancia dentro de la fruticultura nacional (Figura I.1), según datos publicados por el Servicio de Información Agroalimentaria y Pesquera (SIAP), en México en 2014 existen aproximadamente 170 mil hectáreas sembradas de todas las variedades de limón, y con un valor de la producción, de 9,989,668.51 pesos (SIAP, 2014). De acuerdo a los reportes de avances de siembras y cosechas de esta misma institución, en 2014 se produjeron 2.18 millones de toneladas de este producto, lo que representó un incremento del 6% con respecto a 2013, donde se produjeron 2.06 millones de toneladas.

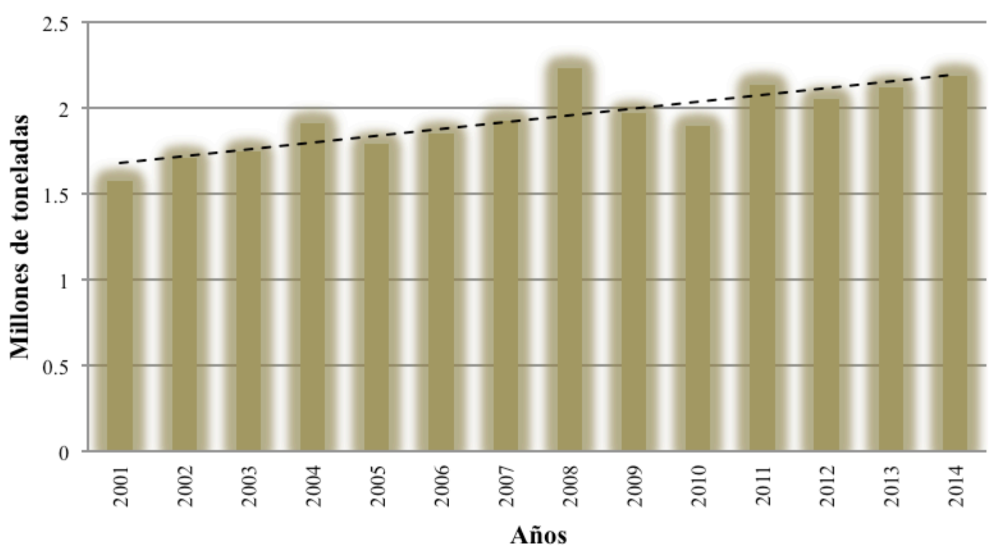

Figura I.1. Producción nacional de limón en México 2001 - 2014
Fuente: Elaborada con datos del SIAP. Consultado en Octubre 2015

La participación de los estados en la producción nacional de limón en 2014 fue de la siguiente manera:

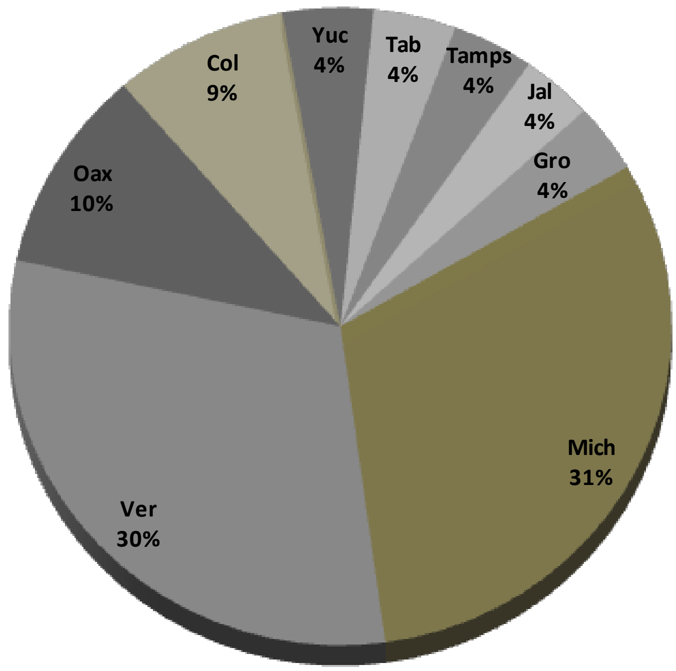

Figura I.2. Participación de los Estados en la Producción de Limón en 2014
Fuente: Elaborada con datos del SIAP

La Figura I.2. muestra que en 2014, en primer lugar de producción se encuentra Michoacán con una producción de 636,768 toneladas, en la mayor parte de limón mexicano, lo que representó el 31% de la producción nacional. En segundo lugar estuvo Veracruz con producción de 623,062 toneladas, en mayor parte de limón persa, lo cual aportó el 30% de la producción total; En la tercera posición estuvo Oaxaca, que produjo 210,208 toneladas, de limón mexicano y limón persa, por lo que contribuyó con 10% de la producción nacional; En cuarto lugar se encuentra Colima, el cual obtuvo una producción de 174,615 toneladas, es decir suministró el 9% de la producción nacional, principalmente de limón mexicano. El resto de los diez principales estados productores tienen una producción que aporta en promedio el 4%, cada uno de la combinación de las dos variedades principales.

La producción de limón en México tiene como principal destino el mercado de fruta en fresco, por lo que sus cotizaciones de precios se obtienen principalmente de las centrales de abastos donde el producto es comercializado. El Sistema Nacional de Información e Integración de Mercados (SNIIM) tiene registrados 24 centros de abasto, a partir de los cuales se calcula el precio promedio nacional anual. Este se calcula como el promedio de los precios promedio mensuales reportados en estos 24 centros. En las figuras I.2 y I.3 se pueden observar las tendencias de los`precios de las principales variedades que se producen en México.

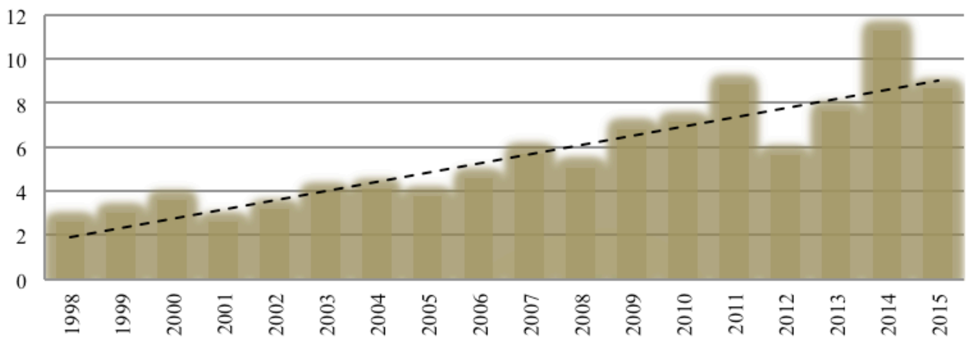

Figura I.3. Precio promedio nacional anual de limón mexicano de 1998 a 2015
Fuente: Elaborada con Datos del SNIIM 2015

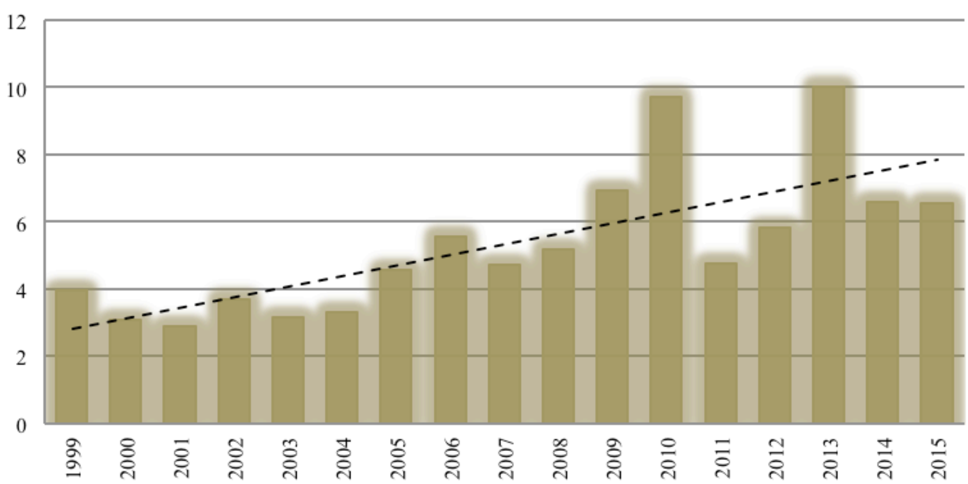

Figura I.4. Precio promedio nacional anual de limón persa de 1998 a 2015
Fuente: Elaborada con Datos del SNIIM. 2015

Es importante mencionar que el limón en México también tiene otros destinos. Aproximadamente entre el 16% y el 30% de la producción total de limón se va a la producción de aceites esenciales, para la industria juguera y para producción de cáscara seca. Estos destinos son los menos preferidos por los productores; ya que, se cotizan a un precio 50 % inferior al observado en centrales de abasto. Los estados de Colima y Michoacán reportan que hasta el 30% de su producción se puede ir hacia la industria procesadora (USDA, 2014).

Durante 2014 se exportaron 510 mil toneladas de limón, entre limón persa y mexicano (Figura 1.5), lo que representó el 23% de las 2.18 millones de toneladas producidas a nivel nacional. Dependiendo de la demanda que se tenga en Estados Unidos, entre 50 y 60% de la producción de limón persa proveniente de Veracruz se destina para atender esta demanda. Por otro lado, los estados de Colima y Michoacán contribuyen de 10 a 12% de la exportación total nacional. Durante 2007 se exportaron casi 71 mil toneladas de limón agrio, mejor conocido como limón mexicano, lo cual representó 13% de las 537 mil toneladas exportadas durante este año (USDA, 2014).

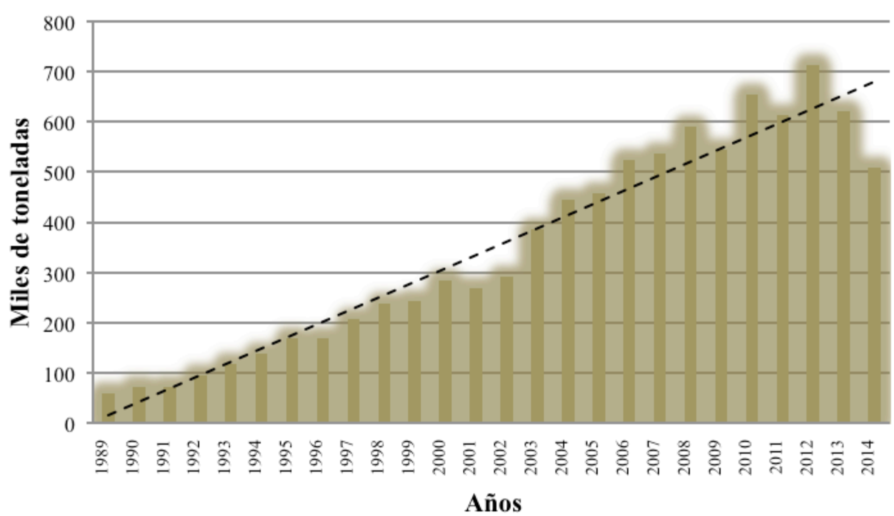

Figura I.5. Exportación anual de limones y limas de 1989 a 2014

Fuente: Elaborada con datos del SNIIM. 2015

Del 23 a 25% de la producción nacional total de limón, que representa el mercado internacional, principalmente se dirige hacia los mercados de Chicago, Atlanta, Dallas, entre otros en Estados Unidos, de acuerdo con el SNIIM. La variedad de limón que se consume preferentemente en el mercado estadounidense es el limón persa o limón sin semilla. Alrededor del 10% de las exportaciones totales corresponden a limón mexicano, lo anterior con base en los datos publicados por el Sistema Información Agroalimentaria y Pesquea (SIAP).

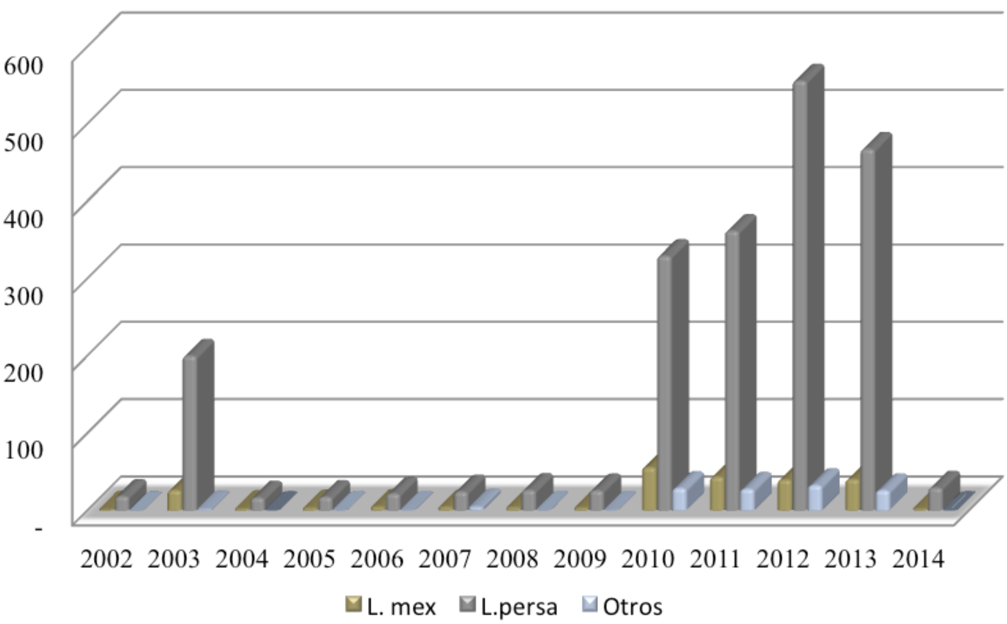

Figura I.6. Proporción de exportación anual por variedad de limones y limas de 2002 a 2013 y preliminares de 2014
Fuente: Elaborada con datos del SIAP. 2015

Sánchez-Torres et al. (2011) señala que en 1982, Estados Unidos cerró la frontera para el limón mexicano proveniente de Colima y Michoacán, por problemas fitosanitarios como la bacteriosis de los cítricos, lo cual favoreció el surgimiento del limón persa en el mercado. Aunado a lo anterior, en Estados de Unidos de América, el limón doméstico sufrió severas pérdidas debido a que se presentó la gran helada de Florida en 1989, el huracán Andrew en 1992 y las heladas de 1995. Todo lo anterior, dio lugar a la reafirmación (Baldwin y Jones, 2012, Schwentesius Rindermann y Gómez Cruz, 2005) e inicio del pleno dominio del limón persa, el cual abastece en más de un 90% al mercado estadounidense. En la década del 2000 al 2010, las barreras fitosanitarias fueron superadas por los productores de limón mexicano, por lo que el mercado de cítricos en EEUU se convirtió en una oportunidad de expansión para los productores de limón mexicano (Baldwin y Jones, 2012).

La superación de las barreras fitosanitarias dio lugar a cambios en la forma de producir el limón en Colima, por lo que empezaron a observarse incrementos en rendimientos, y por tanto en producción (Sánchez Torres et al., 2011). Lo anterior se vió favorecido por incrementos constantes en el precio de exportación, de acuerdo con lo registrado por SNIIM (2012), en la década de 2000 a 2010. Similarmente, de acuerdo con el sistema de información estadística agroalimentaria de México (SIAP, 2015), el limón mexicano presenta tendencia de crecimiento en rendimientos, producción y precios, en el periodo mencionado.

En 2010 se registró en Colima la presencia de HLB (Robles-González et al., 2013), con lo que una serie de acciones de manejo fitosanitario se llevaron a cabo, tanto desde la arena del gobierno federal, como de los citricultores. La recomendación general fue rapidez en la aplicación de las estrategias de manejo fitosanitario. China; Brasil y Estados Unidos ya estaban lidiando contra esta enfermedad de los cítricos, quienes manifestaron haber contenido la infestación de cítricos con el psílido asiático (PAC) y por lo tanto haber frenado de manera preventiva la infección que provoca la bacteria Ca. *Liberibacter*, transmitida por el PAC, cuyas consecuencias son la muerte de los árboles.

El Dr. Joseph Bové (Gottwald et al., 2007) es en la actualidad el fitopatólogo más renombrado mundialmente, por haber promovido la estrategia China para combatir HLB , diseñada en los 60´s por el Dr. K. H. Lin (Xia et al., 2011). Este último, también fitopatólogo, estudió la enfermedad y puso en práctica por primera vez la estrategia conocida como de los “tres componentes (tripié)”, que consiste en el control del psílido, la eliminación de árboles sintomáticos (diagnosticados postivos) y el replante con plantas libres de la enfermedad (de viveros certificados), como la única forma de controlar el HLB, debido a las características de la bacteria y de su vector.

Esta estrategia fue defendida por el Dr. Bové, durante el IV Congreso Internacional sobre Investigación en HLB que se llevó a cabo en Orlando, Florida en el 2015, como una estrategia preventiva. Investigadores de Brasil apoyaron con evidencia la aplicación exitosa de la estrategia recomendada por Bové. Sin embargo, hasta el año 2014, las características del HLB no habían permitido, su control efectivo, ni siquiera donde se habían tomado en cuenta tanto el comportamiento y biología del psílido, como el nivel de infección de la bacteria (Bassanezi, 2015).

Por lo anterior, el presente trabajo contribuye a conocer los elementos que rodean las decisiones en materia de política pública en los diferentes niveles de actuación, especialmente la respuesta de los productores de limón mexicano en Colima. Considerando que, las decisiones de política fitosanitaria que repercuten en el incremento de bienes públicos dependen de que los hacedores de las mismas tengan información oportuna sobre los impactos económicos de las políticas que se aplican. Así mismo, se requier conocer las alternativas que deberían ser consideradas, con el fin de que los tomadores de decisiones apoyen la política de mayor beneficio público, que mejore el diseño y redefinición de la misma (Outlaw, 2011).

I.2. Planteamiento del problema

La diseminación del HLB en el mundo se ha explicado con base en múltiples factores, pero el de mayor peso es la falta de seguimiento, por parte de los productores, de la estrategia de tres componentes divulgada por el Dr. Bové y promovida por las organizaciones de productores y las autoridades fitosanitarias mexicanas. Por lo anterior, se establece como la pregunta de investigación principal: ¿a qué nivel o con qué rigor los citricultores en Colima han adoptado el cumplimiento de la política pública fitosanitaria para el combate al Huanglongbing y los efevtos económicos potenciales de su adopción?

I.3. Justificación de la investigación

El diseño de este trabajo tiene su origen en la expansión del mercado, que el limón mexicano presentó durante la década de 2000 a 2010 (figura I.1, I.5 y I.6), y en el fenómeno que se presentó, en abril de 2010, en las huertas de limón mexicano. En el estado de Colima, las huertas se vieron infectadas, en más de un 60%, por la enfermedad denominada enverdecimiento de los cítricos o HLB, a pesar de la operación oportuna de una campaña estructurada y organizada para combatirla, que empezó a operar desde 2008 con el fin de detectarla y controlarla oportunamente.

El planteamiento del primer artículo inició con el interés de determinar las razones que explican porqué los productores adoptan una campaña fitosanitaria. Por lo que después de haber aplicado una serie de entrevistas a productores en Colima, durante 2011 y 2012, se encontró que los productores estaban decididos a no erradicar los árboles infectados (aún en producción) y en cambio aplicar fertilizantes a los árboles de cítricos que presentaran síntomas de HLB, con el fin de compensar los síntomas de la enfermedad que aparecen como deficiencia de nutrientes. Por tanto, esta estrategia solo incrementa la cantidad de árboles infectados y por ende incrementa la demanda de fertilizantes para compensar los síntomas. Por lo anterior, se elaboró un modelo que explica las interacciones entre las variables clave que forman parte de la oferta y la demanda, y el impacto del uso de fertilizantes sobre la ecuación de oferta. Este trabajo se elaboró sobre todo porque ésta fue la estrategia asumida extra oficialmente por los productores, quienes hicieron atención parcial de la estrategia oficial de los tres componentes.

En el segundo artículo, que forma parte del análisis del problema de investigación, se realiza un análisis de la relación beneficio-costo de aplicar la estrategia de los tres componentes, que consisten en combatir al psílido asiático de los cítricos, remover árboles diagnosticados postivos con HLB y replantar con árboles libres de esta enfermedad. De acuerdo con investigadores en Brasil, esta premisa tiene su base en el conocimiento técnico-empírico de la incidencia y la severidad de la enfermedad en los árboles en riesgo (Bassanezi y Bassanezi, 2008).

En el tercer artículo se examinan las consecuencias económicas en la aplicación de políticas públicas, la adopción de especies mejoradas y aplicación de vacunas para superar la afectación por HLB y mantener la producción de limón. Se analizan políticas asociadas a la sanidad vegetal, ya que son las que permitirían superar las barreras arancelarias de tipo fitosanitario, que imponen los países hacia donde se exporta el producto y sus derivados y porque son las que permiten la subsistencia de la actividad, ante amenazas de enfermedades en cultivos como el Huanglongbing (HLB) o el virus de la tristeza de los cítricos (VTC).

I.4. Marco teórico

Con el fin de establecer el marco de referencia para la aplicación de políticas fitosanitarias se realizó una búsqueda bibliográfica, para determinar cómo son aplicadas en otros países. Principalmente, se buscaron las políticas que se aplican en países productores de cítricos en el mundo, como son Estados Unidos, China y Brasil (FAO, 2007).

Se encontró que lidiar con el HLB ha sido una larga historia, desde finales del siglo XIX en Asia, los patólogos chinos identificaron la enfermedad en los años 50´s (Xia et al., 2011). Kung Hsiang Lin, de la Universidad Agrícola del Sur de China (SCAU) condujo una serie de proyectos de investigación, enfocados en evaluar el impacto del HLB y los efectos de diferentes tratamientos, incluida la aplicación de nutrientes y la modificación de diversas prácticas culturales. Entre los 50s y los 70's, el Dr. Lin (Xia et al., 2011) observó que los cítricos tenían diferente comportamiento de acuerdo a la especie (naranja, toronja, mandarina o lima) al aplicar diferentes dosis de nutrientes, asociados con poda e irrigación oportuna. Sin embargo, los síntomas del HLB, a pesar de que en muchos de los casos fueron disminuidos, nunca fueron eliminados.

A finales de los 70´s también analizó la importancia del psílido en la transmisión de la enfermedad, por lo que propuso la estrategia del tripie o de los tres componentes para el combate al HLB, la cual consiste en eliminación del inoculo removiendo los árboles infectados, uso de plantas libres del patógeno para replantar y control estricto del insecto vector para minimizar la transmisión de árbol en árbol (Xia et al. 2011). Esta es la estrategia que se ha venido aplicando por más de 50 años en China, y que a través de una investigación más avanzada, ha minimizado las pérdidas causadas por el HLB. No se ha logrado la erradicación, debido a que no es práctico eliminar todos los árboles con presencia de la bacteria y tampoco se logra erradicar completamente el vector, que en el caso de México es el psílido asiático de los cítricos *Diaphorina citri* (Kuwayama).

Una historia, similar a la China, fue vivida en Colima, cuando se dio el primer registro de árboles infectados con HLB, aunque no se esperaba una afectación muy grande. En la estimación del impacto económico del HLB, Salcedo Baca et al. (2011) señalan que por las características de la infección en Florida, Belice, Cuba y la República Dominicana, la especie con más probabilidades de verse afectada era la naranja dulce. Pero las características fenológicas, el clima y la adaptabilidad del psílido a las condiciones de Colima, generaron un escenario diferente.

Desde 2009, cuando se detectaron en Yucatán árboles con HLB, el combate al HLB fue oficializado a través de la norma NOM-EM-047-FITO-2009, la cual entró en vigencia inmediatamente. Esta norma emergente dio base para la emisión de dos protocolos denominados: “Protocolo de actuación para la detección del Huanglongbing (PAD-DPF-HLB)” y “Protocolo de actuación ante la emergencia por la detección del Huanglongbing (PAE-DPF-HLB)” los cuales se aplicaron inmediatamente.

A pesar de esto, la enfermedad continuó esparciéndose y después de las detecciones en la península de Yucatán, las siguientes detecciones se dieron en estados de la costa del pacífico del país, comprendiendo los estados de Colima, Jalisco y Nayarit. Para Agosto de 2010, se publicó en el DOF (Diario Oficial de la Federación del 16 de Agosto de 2010) el “Acuerdo por el que se dan a conocer las medidas fitosanitarias que deberán aplicarse para el control del Huanglongbing (Candidatus Liberibacter spp) y su vector”. Sin embargo hubo una gran renuencia por parte de los citricultores para cumplir con toda esta normatividad. De acuerdo con Robles et al (2013) (Investigador del INIFAP), en menos de un año se tenía hasta 60% de árboles con síntomas, aunque los árboles de limón seguían siendo productivos.

Por último, en diciembre de 2012 se publicó el “Protocolo para establecer áreas regionales de control del Huanglongbing y el psílido asiático de los cítricos (ARCOS)” con el objeto de impactar las poblaciones del vector del HLB mediante su manejo en áreas amplias y de esta manera confinar y reducir el avance del HLB en el país.

La literatura consultada de las experiencias en otros países permitió conocer que en Florida, EUA, la presencia del vector se registra desde 1978 (Halbert, 2005), pero no se observaron acciones de combate hasta que se encontraron árboles sintomáticos en 2005 (Hall, 2011).

Aunque algunos citricultores adoptaron la estrategia del tripie, la mayoría de los productores de Florida decidieron conservar los árboles, porque habían pasado una crisis mayor, derivada de la presencia de Cancro, la cual causó pérdidas millonarias, justo antes de la llegada del HLB (Spreen et al., 2013). Por lo anterior, la mayor parte de productores se apegó a la aplicación de nutrientes y al uso de activadores del sistema inmunológico de los árboles, combinando un robusto programa de aplicación de químicos para erradicar al psílido y la aplicación de control biológico del vector en las zonas que así lo permitieron (Rouse, 2013).

Por tanto, la aplicación masiva de insecticidas, nutrientes y demás agroquímicos que mantienen la producción, sólo puede ser costeada por los citricultores grandes que cuentan con mayor capacidad económica (Muraro, 2010). En el último trimestre de 2014, el USDA y diversas organizaciones de citricultores lograron que la Ley Agrícola de Estados Unidos de América "Farm Bill" compensara a los productores que hubiesen erradicado por la presencia de HLB, a través del Tree Assistance Program for Florida Citrus Greening (TAP). Este programa favorece principalmente productores pequeños y medianos organizados y reconocidos ante sus pares para ser apoyados y compensados económicamente al realizar la erradicación de árboles infectados.

Por su parte en Brasil, la presencia del PAC se registró desde 1942, pero los psílidos infectivos y árboles infectados se encontraron hasta 2004 (Belasque et al., 2010). Las experiencias documentadas en Brasil dejan claro que la incidencia del patógeno puede ser minimizada, siempre y cuando exista un control temprano y estricto del vector. Sin embargo, este control del vector sólo ha sido logrado por los grandes productores, los cuales desplazaron a los productores medianos y pequeños, y se adjudicaron la totalidad de la producción, debido a que son los que están en capacidad de producir controlando el HLB (Miranda et al., 2011).

De acuerdo con Bové (2014), sólo 18 empresas han sido capaces de mantener los niveles de incidencia de HLB entre 1 y 2%, índice que permite una producción rentable, apoyando lo señalado por Miranda (2011).

Es importante mencionar que el Departamento de Defensa Agropecuaria de Brasil emitió una serie de normativas como la "Instrução Normativa Nº 53", del 16 de octubre de 2008. Este documento está diseñado con el fin de establecer las medidas cuarentenarias contra el HLB, erradicación de árboles infectados, condiciones de viveros certificados y el uso de plantas libres de HLB. Sin embargo, la responsabilidad del control fue completamente delegada a los citricultores, quienes cuentan a su vez con agencias de investigación que apoyan el control del HLB, como Fundecitrus y Embrapa (Bové, 2012).

El conocimiento de las acciones anteriores proporcionó las bases para incluir las teorías de Olson (1965), sobre la lógica de la acción colectiva dentro de la lucha contra el HLB. Los trabajos de este autor proveen el entendimiento sobre cómo grupos privilegiados son los que en un momento dado alcanzan el bien privado de control de la enfermedad. Sin embargo, un “bien” como la fitosanidad, después de convertirse en un bien privado, sólo es adquirido por los privilegiados. La naturaleza de la enfermedad, del vector y de los citricos, e incluso las condiciones del mercado presionan a estos grupos favorecidos a que el bien privado se convierta en un bien público, en orden de conservar el bien privado original, dando lugar para "free riders".

Estos últimos son productores que tuvieron “la oportunidad” de seguir produciendo a pesar de invertir al mínimo en el combate a la enfermedad. Estos individuos, menos activos, son los que se benefician en primera instancia de la inversión de los grupos privilegiados que son capaces de adquirir o de aplicar las estrategias de combate a plagas y enfermedades en grandes extenciones, con el fin de conservar la producción y últimamente el negocio.

Un aspecto perjudicial de los "free riders" al beneficiarse de los controles ejercidos por otros, es que divulgan que muchas de las enfermedades "no fueron tan graves como se les advirtió o que sus amenazas fueron exageradas" (Diario de Colima, 2013). Estos fueron los casos del VTC, y del HLB entre 2010 y 2015 en algunas de las regiones productoras de cítricos en Colima y Veracruz (Diario el Martinense, 2014).

De acuerdo con Laswell (en Aguilar, 2003) es necesario aumentar la racionalidad de las decisiones de política pública. Esta orientación tiene una doble dimensión, por una parte se interesa en el proceso de la política y por otra en las necesidades de inteligencia de este proceso. Las ciencias sociales en la Región de América del Norte han dado gran importancia al perfeccionamiento del método cuantitativo o econométrico.

El resultado ha sido un aumento en las capacidades para generar mejores metodologías en el procesamiento de datos. Sin embargo, en el pasado, los aspectos cuantitativos siempre se subordinaron a explicar los aspectos sociales. Desde los noventas, el enfoque de políticas, ponía el énfasis en los problemas existenciales del hombre en sociedad, con un enfoque en la cuantificación econométrica. Por consiguiente, las ciencias que apoyan el diseño de políticas sólo podrían avanzar si se afinaban los métodos de obtención de información en campo y en la interpretación del juicio del decisor (Laswell en Aguilar, 2003).

La teoría relacionada con el estudio de las políticas debe tomar en cuenta el contexto completo de los eventos de interés (pasado, presente y prospectivo) (Godet, 2000). Por lo anterior, para que el estudio de política pública pueda ser convincente se requiere de utilizar modelos econométricos del proceso y de apoyarse en las técnicas de cuantificación (Godet, 2000 y Laswell en Aguilar, 2003).

Adicionalmente, cuando se piensa en términos de políticas públicas, es esencial utilizar modelos cuya elaboración permita al investigador tratar con situaciones que integren tantos aspectos como sea posible y por complejos que sean, como es el caso del HLB y la coordinación interinstitucional que se ha dado para su combate. Esto permite llegar a resultados creativos a partir de modelos de procesos, los cuales pueden unificar observaciones cuantitativas y no-cuantitativas para señalar el camino de nuevas actividades empíricas, teóricas y de política (Laswell en Aguilar, 2003).

Otro de los conceptos teóricos importantes en este proyecto es el de prospectiva estratégica (Godet, 2000), la cual apoya que las decisions de política pública requieren de estudios diseñados con el objetivo de aumentar la racionalidad de las decisiones. Según Godet, la prospectiva se aplica para explorar las posibles y/o probables evoluciones futuras de los tomadores de decisiones como son: empresas, grupos, sectores, organizaciones, instituciones, etc., ante temáticas o problemáticas de toda índole como las políticas, económicas, tecnológicas, sociológicas, etc., a mediano y largo plazos (Godet, 2000).

Los productos formales de reflexión prospectiva pueden ir más allá de la presentación de escenarios y más allá de la planeación (Godet, 2000). Es necesario desarrollar una visión estratégica de guía en la cual se incluya el diseño de escenarios como el más probable, optimista y pesimista. Esta definición de escenarios está asociada con la visión de los riesgos y con la determinación del beneficio y el costo en la toma de decisiones.

Así mismo, el marco conceptual de este proyecto de investigación tiene su base en la teoría económica aplicable para generar escenarios que presenten las diferentes alternativas a los hacedores de política pública (Outlaw, 2011). Los escenarios planteados presentan las opciones de política pública y los escenarios económicos asociados sobre los cuales estos actores pueden basar sus decisiones. Dentro de los conceptos a tomar en consideración al plantear la generación de escenarios se encuentra el de Riesgo Económico. Este concepto implica la medida de las posibles eventualidades que pueden afectar al resultado de explotación de una unidad económica y que hacen que no se pueda garantizar ese resultado a lo largo del tiempo (Richardson et al. 2000).

I.5. Objetivos de la investigación

Objetivo General

Analizar las acciones de política pública fitosanitaria aplicada para el combate del HLB en el cultivo de limón y efectos económicos potenciales de su adopción.

Objetivos Específicos

- Identificar las relaciones entre las variables que explican la oferta y la demanda de limón por medio de un modelo de ecuaciones simultáneas, así como determinar el comportamiento de estas variables en el mercado nacional y de exportación a

Estados Unidos de América y su asociación con la toma de decisiones de los citricultores sobre el combate al HLB

- Cuantificar el costo–beneficio de la estrategia de los tres componentes aplicada en Brasil para el control del HLB, en la producción de limón mexicano en Colima.

- Determinar la viabilidad económica, financiera y de flujo de efectivo de la adopción de las estrategias seguidas en Florida, consistentes en tratamientos alternativos y plantación de especies resistentes para combatir el HLB en limón.

I.6. Preguntas de investigación e hipótesis

La principal pregunta, que corresponde al objetivo general de la investigación es:¿en qué medida los citricultores han adoptado el cumplimiento de la política pública fitosanitaria para el combate al Huanglongbing especialmente en Colima y cuales son los efectos económicos potenciales de su adopción?

Las preguntas que corresponden a los objetivos específicos son:
¿Cuáles variables tienen un mayor impacto sobre la oferta y la demanda de limón mexicano? y ¿Cómo las decisiones del citricultor afectan a la oferta y demanda?
¿Cuál es el beneficio-costo privado de participar en las actividades relacionadas con mantener el estatus fitosanitario?
¿Es viable en México la adopción de especies mejoradas, GMOs o vacunas que se están aplicando en otros países citricultores, con el fin de coadyuvar a su permanencia en el mediano y largo plazo?

La hipótesis que mantendremos a travéz de este trabajo es que para los productores de limón es rentable adoptar las estrategias de combate al HLB.

I.7. Contenido de la tesis

El presente trabajo se diseñó en la modalidad de artículos y consta de seis capítulos, los cuales se presentan en la Figura I.7. En el primer capítulo se describe la introducción al tema de investigación y en la cual se proporciona información sobre los antecedentes y alcances de la investigación, se presenta el marco teórico y el marco de referencia que sustentan la tesis doctoral, se establece el objetivo general y posteriormente se explica la estructura de la tesis y los aportes de la misma sobre el tema.

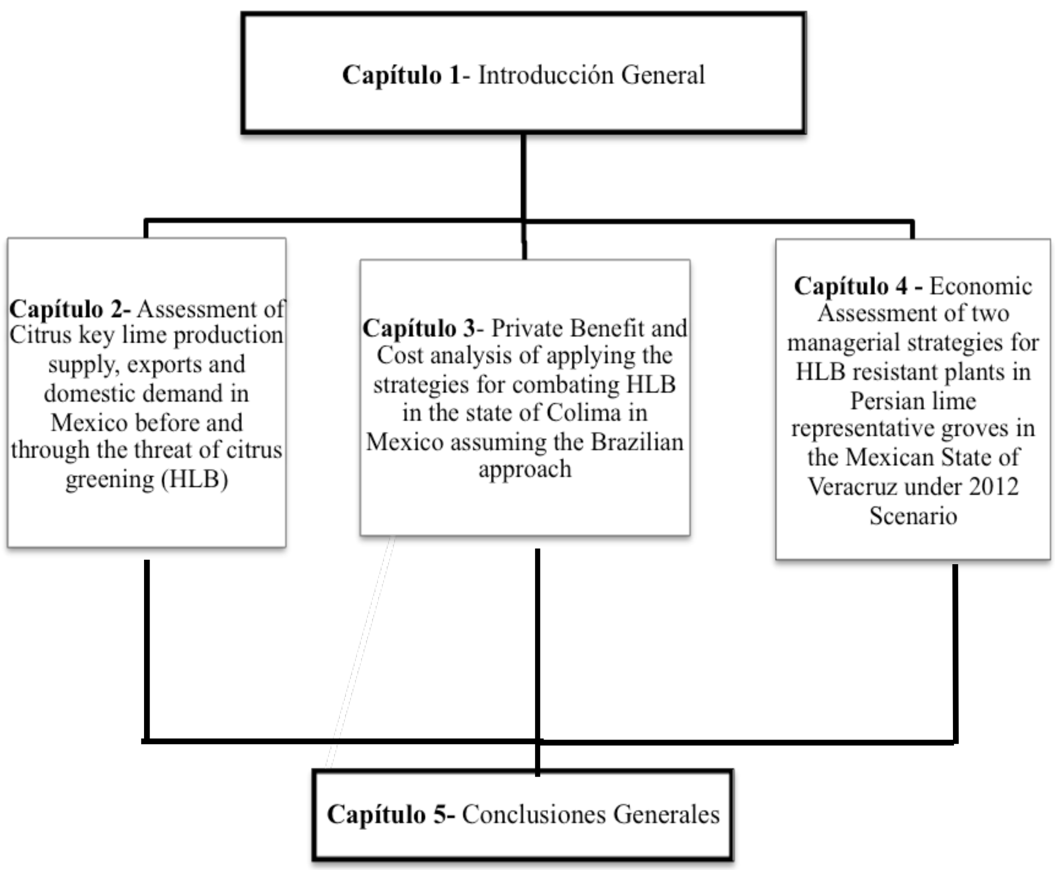

Fig. 1.7. Estructura de la investigación

En el capítulo 2 se realiza un análisis de la oferta y demanda de limón mexicano, tanto en México, como en Estados Unidos y cómo éstas podrían verse afectadas por la primer decisión que toman los citricultores ante la amenaza del HLB, que es la aplicación de mayores cantidades de fertilizantes. En este apartado se examinan las relaciones entre las variables que influyen sobre la oferta de limón mexicano tomando en cuenta al limón persa, así como su respectiva demanda, tanto para el mercado interno como para el de Estados Unidos de América. Lo anterior, bajo el escenario de un mayor uso de fertilizantes como la estrategia preponderante para responder contra la amenaza del HLB o enverdecimiento de los cítricos. El modelo de ecuaciones simultáneas se construyó usando las bases de datos de instituciones y organismos tanto nacionales e internacionales. Las relaciones más importantes entre variables dentro de la ecuación de la demanda fueron el precio del limón mexicano y el ingreso disponible; mientras que por el lado de la oferta fueron el uso de fertilizantes y la tasa de cambio.

En el capítulo 3 se integran los resultados de las entrevistas realizadas en el estado de Colima, principal productor de limón mexicano en el año que se detectó el HLB y se hace un análisis sobre la adopción de la política fitosanitaria y de su relación beneficio - costo. Las recomendaciones oficiales para combatir el HLB se encuentran basadas en los estudios de renombrados fitopatólogos que han tomado en cuenta la endemicidad de la bacteria, como en los conocimientos de entomólogos sobre la biología del psílido. La estrategia fitosanitaria consiste en: A) Erradicación de árboles sintomáticos (diagnósticados como positivos), B) Replantar árboles con árboles libres de HLB provenientes de viveros certificados y C) Controlar el psílido asiático de los cítricos que se encarga de transmitir la enfermedad del HLB de árboles infectados a árboles sanos.

Este artículo documenta los esfuerzos internacionales para combatir el HLB y los incentivos económicos que los productores tienen para alinearse a cumplir con las estrategias para controlar el HLB. La relación beneficio-costo se usa para estimar la viabilidad de la aplicación de las estrategias para combatir el HLB en Colima, probando tres escenarios de cumplimiento: nulo, medio y total de las estrategias de los tres componentes recomendada por el Dr. Bové (2006). Esta técnica toma como base la metodología que se usó en Brasil por las 18 empresas citadas por Bové (2014) y que es administrada por la agencia Fundecitrus.

Esta técnica está basada en el uso de un modelo econométrico, que utiliza la estimación del número de árboles y sus edades al momento que se presentó el brote; estima la dispersión de la enfermedad, con base en un modelo epidemiológico que también toma en consideración la incidencia y la severidad de la enfermedad, que se observó en árboles de naranja. Por otro lado, científicos mexicanos del INIFAP corroboraron que la dispersión del HLB en naranja dulce de Brasil es similar a la observada por el HLB en limón mexicano en Colima (Robles González et al., 2013).

En el capítulo 4 se analizan estrategias, tales como la adopción de variedades resistentes y aplicación de vacunas, y el impacto que éstas pueden tener en la viabilidad general del cultivo de limón. En este trabajo se evalúa la viabilidad económica (económica, financiera y de flujo de efectivo) de dos estrategias de manejo de Huanglongbing (HLB), en Unidades Representativas de Producción (URP) de limón persa, en el municipio de Martínez de la Torre, Veracruz.

En el capítulo 5 se presentan las conclusiones generales, y se establecen las posibles implicaciones de política pública, que las estrategias de manejo fitosanitario puestas en consideración tendrían como consecuencia y cuáles serían las opciones que tendrían los citricultores para lidiar con el HLB.

Capítulo II.- Assessment of Citrus key lime production supply, exports and domestic demand in Mexico before and through the threat of citrus greening (HLB)

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Abstract/

This project looks for the relationship among variables influencing Mexican key lime supply and demand in the domestic and US market under the scenario of using a higher quantity of fertilizers as a strategy for responding against the threat of citrus greening (HLB). With the help of domestic and international databases from 2000 to 2012, a simultaneous equations model was built capturing behavioral and technical variables influencing supply and demand. The most important relationships among variables were price of the product and disposable income for the demand and use of fertilizers and exchange rate for the supply. This work gives the insight, from the economic point of view, that building a model including the right key variables will give a sense of the general structure of a market and the changes in stability due to a plant health threat.

Key words

Mexican citrus, key lime, supply, demand, econometrics.

II.1.Introduction

For the last 20 years, the United States of America (US) has been the world first importer of citrus limes, which include the species Citrus aurantifolia Swingle, or better known as key lime or Mexican lime (FAO, 2012; Baldwin and Jones, 2012). This is because citrus productions in the states of Florida, Texas and California were severely diminished after harsh climatic events in these three states. In the last two decades, Mexico has been the main provider for such crops (Baldwin and Jones, 2012). Persian lime is the main Mexican export citrus lime considering volume and production. Mexican key lime had not enjoyed the same market because of phytosanitary barriers that were imposed 20 years ago into key

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lime production. These barriers were overcome, opening opportunities to Mexican key lime producers in the US markets. However, since 2009, citrus greening or Huanglongbing (HLB) was first detected in Mexico and it has been affecting citrus production, especially the Mexican key lime (SENASICA, 2012; NAPPO, 2012, USDA-APHIS 2012). HLB has been, in the last century, the most damaging disease worldwide detected in all species of citrus (orange, lime, lemons, grapefruit, mandarin and tangerine). HLB emerged in 2004 and 2005 in Brazil (Colleta Filho et al., 2004; Teixeira et al., 2005) and the US (Halbert, 2005), respectively, the two largest orange citrus-growing countries worldwide (Bové, 2006; Gottwald, Da Graça, and Bassanezi, 2007). Citrus greening makes trees die because of lack of nutrition lasting about five years since first detected as symptomatic. During the process of disease deterioration, the citrus trees' yield lessens progressively. So, losses on diminished yields are up to 20% (Bové, 2006). Citrus producers' phytosanitary measures have changed cultural activities, using much more pesticides and increasing the use of fertilizers, and these have been the causes for strong increments in costs (Salifu et al., 2012; Roka, 2011). Foliar applications of micro-nutrients constitute a strategy being employed by an increasing number of Mexico and Florida citrus growers to mitigate HLB debilitating effects (Roka, 2011). All these nutrients and macro-nutrients mentioned in this document are the sources of information for prices in order to build the variable fertilizers in the model. The main objective is to identify relationships among explanatory variables through a simultaneous equations model for the Mexican citrus key lime supply and demand taking in consideration the domestic and US market, such as production, prices, exports, exchange rate and consumption from 2000 to 2012.

As stated before, this document looks for the variables' relationship for defining supply and demand in citrus key lime in the Mexican domestic and US markets, analyzing commercial relationships and building an econometric model consisting in simultaneous equations (Loria, 2011; Hill, Griffiths, and Guay, 2011). The foundation of this analysis is the economic theory which integrated the macroeconomic scenario with microeconomic variables of the decision making process, while integrating the demand equation from the consumers perspective and the supply equation from the citrus growers perspective. Other works that look for the relationship among variables between supply and demand using simultaneous equations models can be found in many arenas of the econometric knowledge, but in the grounds of the Mexican citrus lime agriculture, they are explanatory works about supply, demand, exports and imports especially of Persian lime, the closest substitute for Mexican citrus key lime. The mentioned articles are as the one authored by Sánchez-Torres et al. (2011). In this paper, they built their model under the assumption that the citrus lime market offers a real capacity for expansion to the Mexican growers of this crop, therefore, they formulated a multiple regression model, considering the income, exchange rate (peso/dollar), unit import price and the demand of imports, estimated by the method of Ordinary Least Squares (OLS), with annual data from 1994-2008. There are also references from the descriptive papers on the citrus lime markets from the paper written by Schwentesius Rindermann and Gómez Cruz (2005) or the one prepared by Espinosa-Solares and Santoyo-Cortes (1993).

However, the purpose of the present work is motivated by a practical situation under an actual threat in order to capture part of the trend on supply and demand. In the matters of modelling an agricultural market, Choi (2010) in his study used a similar methodology to the one used in this paper. His paper was concerned on how to model an agricultural market, how to analyse the impacts of a certain event (i.e., animal disease outbreak) on the beef market, and what the relationships between different variables and its influence are on this market. Based on the review of these specialized papers, the main variables for modelling the Mexican citrus market are Mexican key lime price, production in tons and exports to the United States, Persian lime price and consumption in Mexico between 2000 and 2012. The model was built using several databases such as the ones kept by Food and Agriculture Organization (FAO), SNIIM, BANXICO, BIE from INEGI and SIAP from SAGARPA. The Hypothesis states if key lime producers are sensitive to key lime price, fertilizer price fluctuations and domestic and international market environment, then the supply and demand curves will be modified by this behaviour.

This paper is divided into the following sections: the introduction and literature review which include a comprehensive review of references either on the key lime market and the information available about the shock created by a phytosanitary threat represented by citrus greening (HLB). The problem statement is supported by the worldwide research on how to deal with an actual problem like HLB, which decreases productivity diminishing yield and, in order to compensate, citrus growers increase one of the elements they have control on, such as fertilizers. This decision would affect first at the microeconomic level but later the macroeconomic scenario. The established economic scenarios can give an overall view on how supply and demand in the citrus key lime market can be modified when citrus growers take a decision in order to solve a problem and consumers have to deal with the cost of such decision as the final recipient of the shock in the supply curve. In order to get all of this done, at the end of this first section a main objective is stated which keeps the purpose of identifying relationships among explanatory variables through a simultaneous equations model for the Mexican citrus key lime supply and demand, taking in consideration the domestic and US market such as production, prices, exports, exchange rate and consumption from 2000 to 2012. The data and methodology section is about establishing the methods and procedures used to accomplish the objective. They mainly consist of building and describing the database structure for the used variables according to recognized econometrics' techniques. The findings section of the paper presents all the outputs, results and discussion obtained from the methodology. The fifth section is conclusion which states that after applying the methodology and examining the results through the analysis of the data, it was accomplished identifying relationships among explanatory variables for the key lime supply and demand such as production, prices, exports, exchange rate and consumption from 2000 to 2012.

II.2. Data and methodology

To accomplish the objective, several activities were done. First of all, to build and describe the database structure for the used variables and from here, the supply and demand model was assembled by, including both, the domestic and the US market. An econometric model of which variables were determined simultaneously based on the exogenous variables interaction influencing the market and the endogenous variables determined by the model was integrated. (Loria, 2011; Gujarati and Porter, 2010; Choi, 2010) The simultaneous equation model looked for a good representation among production, exports and consumption variables.

The sources of information for the model were: the Integrated Markets Information Service from the Mexican Ministry of Economy (SNIIM) for obtaining national and international prices, the Mexican National Institute for Informatics, Geographic and Statistics (INEGI). Production and exports data are taken from the international agency Food and Agriculture Organization (FAO). Exchange rate was taken from the Bank of Mexico (BANXICO). Exports databases were taken mainly from those products sent from Mexico to the United States, since this is the most attractive market for the modern key lime grower. The methodology proposed by Gujarati and Porter (2010), and taken by Choi (2010), was used in this document to prove the hypothesis. In simultaneous models, there is more than one equation for every variable, one per each mutually dependent variable. Parameters were estimated to these models by taking the given information for the overall equation obtained to describe the system.

Variables included were:

- Plm = Key lime price in Mexican distributions centers all over the country
- Plp = Persian lime price in Mexican distributions centers all over the country
- Fer = Fertilizers Cost
- Csmap = Consumption
- Exp = Exports Volume to the United States
- TCN = Nominal Exchange rate
- TCR = Real Exchange rate
- Ydisp = Disposable Income

Once databases were built, a Pearson correlation coefficient was obtained to find out which variables would have a greater impact on key lime demand and supply. Likewise, the rest of the variables were taken in nominal and real values to pick the best fit for the economic model.

At the end, real variables were chosen because they explain best the fit and adjust of the model.

$$\rho_{X,Y} = \frac{\sigma_{XY}}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y},$$

Where:

ρ Pearson coefficient

σ_{XY} covariance (X,Y)

σ_X standard deviation for variable X

σ_Y standard deviation for variable Y

Most of the Mexican citrus growers in the agricultural food sector make their selling decision on the current price and yesterday's price in the central distribution centers. Therefore, a one day lagged variable was included in the model to capture this decision making process.

Prices were considered as the most influential variable on the model because this is the trigger to the decision of supplying more or less volume of products into the market. Fertilizers were also considered of great influence in the model; because this is the variable citrus growers are modifying in order to combat HLB symptoms. Taking remedial applications of nutrients to reduce the effects of HLB are made on sake of prolonging tree health and productivity. However, increasing all type of fertilizers could run the citrus growers out of business because costs would increase significantly.

Exchange rate is one more variable that has a great impact on the supply and demand of citrus limes in Mexico's domestic market and the exports market such as the one established in the United States. Real exchange rate was the one used in this model because it gave the best fit.

The functional relationship among variables for the key lime supply was defined for the following mathematical expression:

$Qo_t = f(Plm_t, Plm_{t-1}, TCR_t, PFer_t, Exp_t)$

Where:

Qo_t = Mexican Key lime supply in kilograms.

$PFer_t$= Real Fertilizers price applied according to the references in the introduction ($/kg)

Plm_t = Real Mexican Key lime price in the domestic central distribution markets in real value in the current time ($/kg)

Plm_{t-1}= Lagged Real Mexican Key lime price in the domestic central distribution markets in real value in the current time ($/kg)

TCR_t = Real exchange rate for national goods and services compared with those in the US.

Exp_t = Exports to the US (kg)

In the supply equation a direct relationship among Mexican key lime supply and price was expected.

$\delta\ Qo_t\ Qo_t$

$_{-}>0\ >0$

$\delta\ Pc_t\ \delta\ Pc_t$

Meanwhile, a negative relationship between Real exchange rate and the price for fertilizers is expected in this same equation.

$\delta\ Qo_t\ Qo_t$

$_{-}<0\ <0$

$\delta\ PFer_t\ \delta\ TCR_t$

On the other hand, the demand equation for a normal good has been built with the main variables as the price of the good, the disposable income and the closest substitute's price. Assuming that Mexican citrus key lime behaves as a normal good because it is consumed along with other normal goods, its demand is defined by the market's Mexican citrus key lime price, the consumption, and the Persian key lime price (its closest substitute). According to the methodology defined by Gujarati and Porter (2010) the functional demand equation would be defined as follows:

$Qd_t = f(Plm_t, Plp_t, Csmap_t, Ydisp_t)$

Where:

Qd_t = Mexican Key lime demand in kilograms

Plm = Real Mexican Key lime price in the central distribution markets in real value in the current time ($/kg) in the current time

Plp_t = Real Persian lime price in the central distribution markets in real value in the current time ($/kg) in the current time

Yd_t = Real National disposable income ($).

A negative relationship is expected in the demand function.

$$\frac{\delta Qd_t}{\delta Plm_t} < 0$$

Meanwhile, demand quantity and Persian key lime price relationship is expected to be positive because Persian key lime is a good that is substituting key lime.

$$\frac{\delta Qd_t}{\delta Plp_t} > 0$$

Since Mexican citrus key lime is assumed as a normal good, quantity demand is expected to increase when consumer income increases; the same is expected when looking at quantity demanded and consumption.

$$\frac{\delta Qd_t}{\delta Y_t} > 0$$

$$\frac{\delta Qd_t}{\delta Csmap_t} > 0$$

Structural and reduced form of the Model

Model Structure

Citrus key lime supply and demand are developed in this section on the basis of empirical knowledge and theoretical information. For each used variable, it is described the data structure and how they fit into the supply and the demand equation. The chosen variables come from the commodity market such as citrus key lime prices, fertilizer prices, volume of production, volume of citrus limes exports and exchange rate for the supply side of the equation. On the other hand, chosen variables for the demand equation are also prices for the closest substitute and disposable income.

As stated above, the model chosen in this analysis is a simultaneous equations model. This model was built based on the methodology according to Gujarati and Porter (2010) and described also by Loria (2011). In these models, variables are sorted into endogenous and exogenous variables. The model determines endogenous variables, while exogenous variables are determined by external conditions. These variables are also identified as predetermined variables and they are independent from the error terms of the model and satisfy the independent variables condition within a classic linear regression model (Gujarati and Porter, 2010).

Demand and supply equations are characterized by sharing prices of the product that is the same endogenous variable. Since there are no correlations among explaining variables as stated in the Linear regression classic model, (Gujarati and Porter, 2010), then the best fit for highly affected data by price and the offered quantities is the simultaneous equations model.

On the demand side, endogenous and exogenous variables stated for modeling the citrus key lime market are the following:

Endogenous variables for model Yi

Qdt = citrus key lime Volume in kg and obtained from consumer consumption

Qot = citrus key lime supply in kilograms obtained from total key lime national production plus imports volume.

Plm_t = citrus key lime price ($/kg) in real terms in the current period.

Exogenous variables for Xi

Plm_t = Key lime price ($/kg) in real terms in the current period in the domestic market.

Plm_t = Key lime price ($/kg) in real terms in the current period in the US market.

TCR =Exchange rate:

Plp_t = Persian lime price ($/kg) in real terms

Yd_t National disposable income $) in real terms

The structure of the model is as follows:

$$Qo_{1t} = \beta_{10} + \beta_{11}Plm_{1t} + \gamma_{11}Plm_{1t-1} + \gamma_{12}Exp_{1i} + \gamma_{13}TCR_{1t} + \gamma_{14}Fer_{1i} + \omega_{1i}$$

$$Qd_{2t} = \beta_{20} + \beta_{21}Plm_{2t} + \gamma_{21}Plp_{2i} + \gamma_{22}Yd_{2ti} + \gamma_{23}Consmap_{2ti} + \omega_{2t}$$

$$Qd_{2t} = Qo_{1t}$$

Coefficients β and γ represent estimated parameters, while ω represents the error term either in the demand or the supply side of the model

Coefficients obtained for each variable on the equation are as follows:

Table II.1. Coefficients β and γ for the estimated parameters

Equation	1	Y_1	Y_2	Y_3	X_1	X_2	X_3	X_4	X_4	X_5
		Qd	Qo	Plm	Plm_{t-1}	Exp	TCR	Fer	Yd	Consamp
1	β_{10}	1	0	β_{11}	γ_{11}	γ_{12}	γ_{13}	0	0	0
2	β_{20}	0	1	β_{21}	0	0	0	γ_{21}	γ_{22}	γ_{23}

Source: Elaboration through Gujarati's methodology.

Identification

When using a simultaneous equations model it is important to identify every structural parameter within the model (β and γ matrix) taking as reference the reduced form of the parameters (π matrix) (Gujarati & Porter, 2010). An equation is not identified when there is not enough information to estimate parameters in the structural form of the equation. A parameter is identified if there are no other parameters that are observationally equivalent. If a parameter is not identified, then the population value of the parameter cannot be deduced by any method with an infinite amount of data. For single equation models, identification fails if the predictor does not vary over observations or if the population covariance of the predictor and the error is not zero. To restore identification, we write the system as if the equilibrium condition allows the replacement of both QDt and QSt with Qt, thereby reducing it to a system of two equations. An equation is over identified when there is more than one possible combination for the estimated parameter values in the structural model.

The sufficient condition for identification is the Rank Condition. For each equation: each of the variables excluded from the equation must appear in at least one of the further equations (no zero columns). Also, at least one of the variables excluded from the equation must appear in each of the further equations (no zero rows). Rank Condition for each equation: the set of variables is considered excluded from the equation. The matrix of coefficients for these variables in the other map of equations must have full row rank.

A structural equation is identified only when the predetermined variables are arranged within the system so as to use the observed equilibrium points to distinguish the shape of the equation under study for which Y1t, Y2t and Y3t are the jointly endogenous variables. The equations in the system are labeled structural equations, as they characterize the economic theory underpinning the determination of each endogenous variable. A variable is endogenous because it is jointly determined (a change in Y1t leads to a change in Y3t, which in turn leads to a change in Y2t). Exogenous variables may appear in all equations, witness X1t as to what is endogenous and what is exogenous, why that depends on the scope of the partial equilibrium model under study. To verify the order condition, it is recognized that there are three predetermined variables in the system (X1t ; X2t ; X3t) and no more than three slope coefficients in any one equation. To verify the rank condition, it was used the following table, in which indicates a variable appears in the given equation and 0 indicates a variable does not appear in the given equation:

Table II.2. Level of identification

Equation	M	M	K	K	K-k	m-1	Identification
1	3	2	6	3	3	1	Over identified
2	3	2	6	3	3	1	Over identified

Source: Elaboration through Gujarati's methodology.

A structural equation is identified only when the predetermined variables are arranged within the system so as to use the observed equilibrium points to distinguish the shape of the equation under study.

Both equations are over identified therefore, for obtaining the parameters the two stages least squares model is the best fit accordingly to the rank condition.

With regard of error term violations multicollinearity tests are done (correlation matrix), heterocedasticity tests and autocorrelation test (Durbin Watson) Error term conditions are not violated after applying these tests.

Also for testing for multicollinearity the Condition Number procedure (Judge et at. 1985) was revised as an optional way to probe that the error terms conditions were not violated. Under this methodology, the condition number (κ) is the condition index with the largest value; it equals the square root of the largest eigenvalue (λmax) divided by the smallest eigenvalue (λmin). As stated earlier, the two stage least squares model is the procedure used for the structural form of the model because it is a very good fit for over identified equations (Loria 2011). The econometric program SAS is used for all related calculations.

II.3. Findings

All the data series were first tested with the Dickey-Fuller test for a unit root test and were found free of a unit root in the analyzed data at the value of t stated as critical. We then search for the existence of correlation in the variables. The correlation matrix is one of the first outcomes analyzed after running the SAS® program. The most relevant interactions are among Mexican citrus key lime price and exports, exchange rate and fertilizers price according to table 3.

Table II.3. Correlation matrix

	TCR	QLimes	PrecioLm	PrecioLm1	PrecioLp	Exp	ConsmAp	Fer	Ydisp
TCR	1 13	0.70179 0.0075 13	0.83883 0.0003 13	0.67418 0.0162 12	0.7452 0.0035 13	0.86636 0.0001 13	-0.1257 0.6824 13	0.57388 0.0403 13	0.87767 <.0001 13
QLimes	0.70179 0.0075 13	1 13	0.58042 0.0375 13	0.73195 0.0068 12	0.70674 0.0069 13	0.83094 0.0004 13	0.1118 0.7161 13	0.74051 0.0038 13	0.84666 0.0003 13
PrecioLm	0.83883 0.0003 13	0.58042 0.0375 13	1 13	0.84466 0.0005 12	0.93055 <.0001 13	0.76885 0.0021 13	0.08296 0.7876 13	0.52359 0.0663 13	0.83184 0.0004 13
PrecioLm1	0.67418 0.0162 12	0.73195 0.0068 12	0.84466 0.0005 12	1 12	0.92855 <.0001 12	0.67517 0.016 12	0.4014 0.1959 12	0.61521 0.0332 12	0.78471 0.0025 12
PrecioLp	0.7452 0.0035 13	0.70674 0.0069 13	0.93055 <.0001 13	0.92855 <.0001 12	1 13	0.75057 0.0031 13	0.32517 0.2783 13	0.62727 0.0217 13	0.87363 <.0001 13
Exp	0.86636 0.0001 13	0.83094 0.0004 13	0.76885 0.0021 13	0.67517 0.016 12	0.75057 0.0031 13	1 13	-0.24686 0.4162 13	0.56549 0.044 13	0.94003 <.0001 13
ConsmAp	-0.1257 0.6824 13	0.11180 0.7161 13	0.0829 0.7876 13	0.4014 0.1959 12	0.3252 0.2783 13	-0.2469 0.4162 13	1 13	0.2102 0.4907 13	-0.0158 0.9591 13

Table II.3. Correlation matrix

	TCR	QLimes	PrecioLm	PrecioLm1	PrecioLp	Exp	ConsmAp	Fer	Ydisp
Precio Fer	0.5739	0.74051	0.5236	0.6152	0.6273	0.5655	0.21017	1	0.66891
	0.0403	0.0038	0.0663	0.0332	0.0217	0.0440	0.4907		0.0124
	13	13	13	12	13	13	13	13	13
Ydisp	0.8777	0.8466	0.8318	0.7847	0.8736	0.9400	-0.01580	0.6689	1
	<.0001	0.0003	0.0004	0.0025	<.0001	<.0001	0.9591	0.0124	
	13	13	13	12	13	13	13	13	13

Source: Elaboration using the SAS output

In table II.2., II.3. and II.4. the results of the estimation of the model of simultaneous equations are shown. These results are taken from the modeling in package SAS and the results shown in Annex.

Table II.4. Variables used in the model basic statistics

Variable	N	Mean	Standard deviation	Add	Least	Maximum
TCR	13	10.96077	1.2933	142.49	9.34	13.5
Qlimes	13	1846969	241800	24010600	1367500	2242540
PrecioLm	13	5939	1973	77203	3834	10019
PrecioLm1	12	5687	1829	68239	3834	10019
PrecioLp	13	4399	1987	57182	2454	9030
Exp	13	354318	100359	4606135	217679	487085
ConsmAp	13	2774829	927141	36072772	1955843	5252302
Fer	13	5126	1268	66634	3483	7057
Ydisp	13	9232381484	3024076488	1.20E+11	4548149425	1.42E+10

Source: Elaboration using the SAS output

Here are the Mexican key lime Supply and demand equations

Supply

$$Qo_{1t} = \beta_{10} + \beta_{11}Plm_{1t} + \gamma_{11}Plm_{1t-1} + \gamma_{12}Exp_{1i} + \gamma_{13}TCR_{1ti} + \gamma_{14}Fer_{1ti} + \omega_{1i}$$

Q_O = -5461.34 - 0.6124Plm_{1t} + 0.000939Exp + 774.65TCR + 0.17Fer

R^2=0.8567

Demand

$$Qd_{2t} = \beta_{20} + \beta_{21}Plm_{2t} + \gamma_{21}Plp_{2i} + \gamma_{22}Yd_{2ti} + \gamma_{23}Consmap_{2ti} + \omega_{2t}$$

$Q_d = 907926.3 - 75.29Plp_{1t} + 0.000111\ Y_{d\ isp1t} + 0.08735Consamp_{1t}$
$R^2=0.7791$

The expected signs on the variables are obtained for the Mexican citrus key lime price, exchange rate and for the lagged price according to these equations. Estimated coefficients on fertilizers price are not as strong as they could be expected, therefore they may need a fine calibration in order to display the production decisions better. The results obtained in the supply function are reflecting the scenario before HLB, therefore, it could be expected an increase among all the costs of production, which compromises fertilizers, management practices, used machinery and labor. It is assumed that the relationship between price of key lime and fertilizers will influence citrus growers decisions more importantly in later observations. The results obtained by Sánchez-Torres et al. (2011) in her citrus supply model found a similar relationship while obtaining the citrus supply function because her data are also reflecting the scenario before HLB. In the paper by Choi (2010), there is also an assumption in his simultaneous equations model about a sanitary threat jeopardizing the beef market on the supply side. The model reflects the shift on the supply equation and the likely scenario on the price. The expected signs in the lagged variable show the producer's speculative behavior. Therefore, if the price of Mexican citrus key lime was low the day before or the previous period, it is expected to increase in the following day or season until oversupply and price decreases again.

Nevertheless small inconsistencies found in the estimation of the model, the supply function shows a relevant price behavior in the current period and correlated to exchange rate. This is the result of rational key lime growers responding to the international citrus market behavior who use the information as the basis of their production decisions. The choice is to cut or not during the 2 to 4 weeks harvesting time accordingly to the geographic region.

On the other hand, the Exchange rate (TCR) variable mirrors the importance of Mexico in the international Limes and Lemons' market and also allows introducing a very relevant external factor to the model. TCR also influences the supplied quantity in the domestic market when there is a market shock in international exchange rate. This variable is also able to mirror the influence of current phytosanitary barriers, which have been a great issue to overcome when exporting Mexican key lime. Besides, TCR and Exports also are means to measure world trade openness and competitiveness in the citrus industry operations

As mentioned earlier and related with tests done to probe violations to the error term, it is found that multicollinearity is the only one that is positive. The rest of the tests results are negative (heterocesdaticity and Durbin Watson). There is not a multicollinearity corrective treatment because all the chosen variables are essential for the built of the model. Analyzing furthermore multicollinearity is expected because many productive and market factors influence one another in different arenas. Therefore, the variables with the greatest correlation have the highest standard errors (Table II.1).

The violations to the assumptions to the error term have to do with residuals are not correlated serially from one observation to the next. This means the size of the residual for one case has no impact on the size of the residual for the next case. The Durbin-Watson Statistic is used to test for the presence of serial correlation among the residuals. The value of the Durbin-Watson statistic ranges from 0 to 4. As a general rule of thumb, the residuals are uncorrelated is the Durbin-Watson statistic is approximately 2. A value close to 0 indicates strong positive correlation, while a value of 4 indicates strong negative correlation (Gujarati and Porter, 2010).

The output from SAS shows under the PROC REG instruction and Model 1 a Durbin Watson of 2.647. Once the program is fixed to run the simultaneous equation model, the output shows that the Demand equation has a Durbin Watson of 2.03 and the Supply equation has a Durbin Watson of 2.073. So, according to Gujaraty et al (2010) and taking the DW = 2 as reference, there is not positive or negative autocorrelation, therefore there are no violations to the assumptions to the error term.

According to Judge (1985) and Allison (2012) multicollinearity is a common problem when estimating linear or generalized linear models, including logistic regression models. It occurs when there are some kinds of relationships among predictor variables, leading to unstable estimates of regression coefficients. Most data analysts assume that multicollinearity is not a desirable. According to Judge (1985), high multicollinearity is a multiple correlation coefficient greater than 80%, but in many cases there are several situations in which multicollinearity can be safely ignored because of the characteristics of the database and the variables. In this case, the demand equation is kind of affected by multicollinearity (Annex 1) because of the low statistic significance in its explicative variables.

The output shows that Mexican citrus key lime Price is inversely related to the demand equation and the Persian key lime price behaves as a commodity substitute. On regard of disposable income, key lime behaves as a normal good because as a meat flavor enhancer in the taste of the Mexican consumer and also to the consumer that looks for citrus key lime in the United States.

II.4. Conclusions

As expected and through the analysis of the data, this study was accomplished by identifying the relationships among explanatory variables for the key lime supply and demand such as production, prices, exports, exchange rate and consumption from 2000 to 2012. The simultaneous equation model methodology is pertinent to finding relationships among endogenous and exogenous variables. This methodology is also appropriate to capture behavioral and technical relationships among the variables that are influencing the supply of key limes such as fertilizers supply for growing citrus key lime trees. Economic theory in this case provides the basis for theoretical reasoning to explain the behavior and trend among these variables relationships. In this case, a practical approach taken by the US and Mexican citrus growers to deal with a citrus sanitary threat and how these interactions exist is depicted in a simultaneous model. While in the supply side citrus growers are increasing fertilizers consumption through applying an intensive foliar and ground fertilization strategy in an attempt to deal with a citrus disease, and in the other hand how the demand side is affected by the increased price of citrus lime because of the increased costs of using higher amounts of fertilizers.

It was found that the most important relationships among variables were price of the product and disposable income for the demand and use of fertilizers and exchange rate for the supply. The expected signs on the variables were obtained for the Mexican citrus key lime price, exchange rate and for the lagged price according to these equations. Estimated coefficients on fertilizers prices were not as strong as they could be expected, may be because there is a high quantity of components in these variables, therefore they may need a fine calibration in order to display the citrus growers' production decisions better. The expected signs in the lagged variable showed as expected the producer's speculative behavior.

Consequently, the price of Mexican citrus key lime was behaving in anticipation to being low the day before and increasing the following day until oversupply and price decreases again. This is the way of inferring the rational of key lime growers responding to the citrus market behavior who use the information as the basis of their production decisions. Though the minor inconsistencies are found in the estimation of the model, the supply function showed a relevant price behavior in the tested term and correlated to exchange rate. The Exchange rate (TCR) variable mirrors the importance of Mexico in the Limes and Lemons' international market and also allows introducing a very relevant external factor to the model. TCR also influences the supplied quantity in the domestic market when there is a market shock in international exchange rate. This variable is also able to mirror the influence of current phytosanitary barriers, which have been a great issue to overcome when exporting Mexican key lime. Besides, TCR and exports are also the means to measure world trade openness and competitiveness in the citrus industry operations.

In conclusion, it was found that the Mexican key lime demand quantity was affected mainly by the market key lime price, Persian lime price and disposable income. The output showed that Mexican citrus key lime Price is inversely related to the demand equation and the

Persian key lime price behaved as a commodity substitute. Regarding to disposable income, key lime behaved as a normal good as a meat flavor enhancer for the taste of the Mexican consumer and also as the substitute for consumer that looks for citrus key lime in the US. The Mexican key lime quantity offered in the 2000-2012 period is mainly affected by the key lime price and the exchange rate and in a lesser degree by fertilizers' price but not as expected because this last variable has many elements such as the time HLB was detected by first time, the time the citrus growers began to apply more fertilizers and account this change in increased prices. Therefore, we failed to reject the hypothesis on whether key lime producers are sensitive to key lime price and fertilizer price fluctuations. In order to have more tools to expose this behavior, it is important to recalibrate the mechanisms inside the model to transfer the performance of the variable fertilizer price to more accurately reflect the use of these chemicals in the strategy against citrus greening (HLB) on the supply side of the simultaneous equation model. Interviewed growers through direct surveys have manifested the increased use of fertilizers in their orchards to compensate HLB damage on citrus trees. Therefore, the supply function has to show the heavier use of this supplement. The citrus growers' rational decision based on reliable international market information has been fulfilled because Mexico so far has been the main provider of lime and lemon to the United States during the last three decades.

From the economic point of view, the impact of a sanitary threat such as citrus greening (shock on the supply side) can devastate the production of citrus and diminish dramatically the supply curve. Therefore building models with the right key variables allow to have a sense on market price and quantity ex ante and ex post, and how these evolve over time in order to improve the decision making process of every stakeholder involved in the industry and public policy designers.

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Capítulo III. Private Benefit and Cost analysis of applying the strategies for combating HLB in the state of Colima in Mexico assuming the Brazilian approach

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Abstract

Mexican citrus-growers witness the Brazilian citrus-industry as a major example while dealing with HLB, the most devastating disease worldwide. This paper analyzes through a benefit cost analysis (BCA) how suitable adopting the Brazilian approach is for Colima's citrus-growers, assuming similar agronomic, economic and biological citrus conditions. The BCA assesses several scenarios (A-B-C-D) deciding how suitable they are to Colima's citrus-groves. Scenario A is stated as production without disease. Scenario B is assuming spread of the disease without any control. Scenarios C and D establish intermediate situations between controlling and eradicating. Productivity depends on levels of incidence of the disease. Costs come from activities related with growing citrus and controlling pests. The BC ratio comparing Scenarios D-B establishes that for every dollar invested on the complete set of strategies, the return is 10.9, and NPV is US$663,292,061 for benefits and US$60,763,607 on costs. Comparing Scenarios, the BCR D-C is -139, with an NPV of US $356,957,641 on benefits and NPV of US $2,562,148.811 on costs. This means the feasible choice is D-B. Similarly to Brazil, Mexican citrus-regions are affected by HLB, so this benefit-cost analysis provides a sense on which strategies to apply in uninfected citrus-regions in other states within Mexico.

Keywords: HLB, Benefit Cost Analysis, Plant Health Program

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III.1. Introduction

After a century of the appearance of HLB (Greening) in the world, it has been qualified as the most severe disease that has ever appeared in the citrus groves because of its consequences (Bové, 2006). Several situations are stated as the possible destiny for the citrus industry in every country that has been affected by HLB (Spreen, 2013). Since China was the first country that officially identified the malady, a renowned pathologist named Dr. K.H. designed the Chinese strategy as a first draft since the middle 70's, which implied eradicating diseased citrus trees, and starting plantations all over again. Later, the role of, *Diaphorina citri Kuwayama,* an Asian Citrus Psyllid, was included in the pathosystem, because this is the vector of which population transmits HLB (Xia, 2011). Thus, to face this threat, this strategy was retaken in 2004 by Dr. Bové from France and recommended in order to control the severe outbreak of greening in Brazil (Bové, 2006).

The Brazilian approach means having a grove management with losses trying to set new plantings and never reaching the maximum point of production because citrus trees have to be eradicated as soon they present HLB symptoms; this also includes replanting of the removed trees and complete replanting every twenty years. The purpose of this paper is assessing several scenarios to obtain the best fit through analyzing the benefit and cost of applying the three-pronged strategy. With the methodology proposed by Miranda (2010, 2011), and Bassanezi & Bassanezi (2008), with the help of Miranda´s team at the University of Sao Paulo and with the data available from State and Governmental agencies such as COEPLIM-Colima State key lime producers Council (2013), INIFAP (Agriculture Research Institute) (Robles, 2011), INEGI (National Institute of Statistics and Geographic Information, 2007) and CESAVECOL (Colima Plant Health Committee, 2013), a benefit cost analysis was built in order to look at several chosen scenarios and to compare which would be the best fit for Colima’s citrus industry.

The Benefit Cost Analysis evaluates the differences between scenarios of different levels of application of the Bové approach. Therefore, benefits are taken from the assumption of keeping the health of citrus trees once replanted. Consequently, productivity is kept at several levels of incidence of the disease (Belasque, 2010), but still without losing the market. Costs are obtained from the activities to grow citrus and from the activities to control pests and diseases including HLB such as elimination of infected plants and increase in production costs (due to inspections, frequent insecticide applications, tree elimination and replanting). Producers' costs of production considered into the model about key lime production across time come from citrus orchard size, inputs for production and crop loss damage.

Besides all the mentioned earlier, the plant health status in 2012 in Colima and also the economic scenario in the same year such as exchange rate dollar/peso, the price paid to the citrus grower and the level of inflation during that year were all taken into consideration for feeding the model. The epidemiological approach in Miranda´s model comes from the calculations made by Bassanezi & Bassanezi (2008) and they are used to project the disease's progress.

Among other works and documents related with building the benefit cost analysis would be the one applied by Salcedo et al (2011) in the book about assessment of the campaign against HLB in Mexico. However, this analysis takes into consideration the whole citrus industry in the country and the analysis is based on the federal public investment for controlling HLB. Further documents using this Private Benefit Cost Analysis methodology are those published by Miranda (2011 and 2010) where the Sao Paulo citrus industry was assessed and the information obtained gave a good input to the Northeast citrus industry from the same country that could be under the same plant health threats suffered by Sao Paulo's citrus industry. There are also documents where the benefit cost assessment was applied in the Floridian citrus industry by Spreen (2013), and those under the threat of citrus canker and the assessment of the program build by Zansler et al (2012). In the same way as Brazil, Mexican citrus regions are affected differently, so the benefit cost analysis in the state of Colima on key lime, shown in this paper may provide good insights to the citrus decision makers of the rest of Mexico, which are still not affected by HLB.

The present document establishes the foundation of the HLB disease in the introduction, and in the methodology section explains how four scenarios were built based on the methodology proposed by Miranda (2010, 2011) using the benefit cost analysis on the citrus production taking in consideration the incidence and the severity of the disease proposed by Bassanezi & Bassanezi (2008) based in the epidemiological Gomphertz model. In the results section, several graphs display the benefits of adopting the strategies according to the stated scenarios. The conclusions chapter establishes that the benefit cost ratio is positive and the investment is worth it in the long run. The NPV is also giving a positive number which suggests that keeping the strategies and assuming the spread, incidence and severity of the disease showed in Brazil as the model for the Colima´s citrus production will allow its survival in the long run.

III.2. Methodology and Data

When building a Benefit Cost Analysis, it is necessary to choose the forecasting horizon, which in this paper was chosen to be 20 years. The year 2012 is important for Mexican citrus growers in Colima, because that year several strategies were tested and several documents were published in order to control HLB, such as the Protocol to establish regional areas for controlling psyllids that transmit HLB (ARCOS). So, the reference year chosen in this paper was 2012, taking the economic conditions that prevailed during this year as foundation as well as the plant health policy enforced in the state of Colima on the citrus groves at that time.

On the other hand, and according to the methodology proposed by Miranda (2010, 2011) the Benefit-Cost model, used in agricultural protection policies, requires of identifying the benefits and the parallel tangible and intangible costs either direct and indirect, involved in the application of a plant health campaign. Once they are acknowledged, and databases are prepared for calculations, it is possible to build scenarios in order to calculate the net present value of benefits and costs under the referenced scenario. In this paper, there will be four scenarios: A with no disease, B with disease but no control, C with disease but just with insecticide treatment and D with disease and control with insecticides and eradication of diseased trees. Once this is stated, and the alternative scenarios are defined, projections can be done for a chosen time horizon analysis. For each scenario outlined, there is a flow of projected benefits and costs present on the time horizon, under the prevailing 2012 economic scenario, such as using a discount rate of 5% (taken as reference from Banxico). With the sum of the present values of benefits and costs, it becomes possible to calculate the benefit- cost ratio. The benefit -cost ratio is calculated according to the equation 1.

$$B/C = \frac{\sum_{j=0}^{n} B_j}{(1+i)^j} / \frac{\sum_{j=0}^{n} C_j}{(1+i)^j} \quad (1)$$

Where:

Bj = Benefits of avoided losses Investment on defense program in the year j ;

Cj = Associated costs with the maintenance of citrus grove in year j (provided by the private sector);

i = discount rate; the discount rate used was assumed at 5%, which is a basic interest rate used in the Mexican economy by Banxico for the UDIBONOS 1A.

n = orchard´s span life.

To evaluate the economic viability of an investment, Miranda´s methodology adopts the method of the Net Present Value (NPV), as it is one of the most used in the field of investment analysis due to its reliability. It is important to remember that, as recommended by Miranda et al. (2010), the actions in favor of plant health may be seen as an investment, because they seek to safeguard production in future periods. The calculation of NPV can be seen in equation 2 and it is closely linked with the Benefit-Cost model.

$$NPV = \frac{\sum_{j=0}^{n} B_j - C_j}{(1+i)^j} \quad (2)$$

An investment is considered feasible, from an economic and financial point of view, when the net present value is higher than zero (NPV > 0). When this occurs, benefits outweigh the costs, and when considering the case of benefit-cost analysis, the value has to be higher than 1, as seen in equation 3. Thus, when NPV > 0

$$NPV = \frac{\sum_{j=0}^{n} B_j - C_j}{(1+i)^j} \text{ and } B/C>1 \quad (3)$$

This number can be interpreted as the return on investment (producer (private) or government (public)); which is the obtained profit for each currency unit invested in the considered action or program of plant health. In this case, the NPV represents the return, or benefit, that a citrus plant health strategy will deliver in the chosen currency units, therefore, benefits are taken from the estimation of keeping healthy citrus trees in a hypothetical scenario and therefore keeping production at several levels without losing the market. Costs are obtained from the activities to control HLB, such as elimination of infected trees and increase in production costs (due to inspections, insecticide applications, tree elimination and replanting), key lime production and costs of production to grow the crop, crop loss damage related to citrus orchard size and the assumption to control the disease over 20 years, and at the end of this time period the producer will replant the whole grove.

So, for this proposed methodology, the plant health benefits come from the valuation of avoided losses by the action of prevention policy, control and eradication of the citrus greening disease. Since this is a private estimation of the benefits and costs of the strategies applied, the costs do not include the government's expenditures through programs or campaigns of plant health. In the same way, Miranda (2011) also states that all the data added up from avoided losses, which are considered benefits, costs have to be converted to net present value at a chosen discount rate (Banxico's 5%); this is an important choice because it influences the results in terms of benefit-cost ratio. The benefit-cost ratio is obtained by calculating the relationship between all the added values of the given benefits and divided by the sum of all the added costs associated to the program of defense of agriculture. It is possible to compare the original and the alternative scenarios because in all the calculations, the variation on the conditions is added up in the same way so the benefit-cost ratio is stated in the same terms. This proposed methodology considers the action of plant defense as an investment. Therefore, an interest rate of 5% annual average was adopted as the long-term interest rate in real values of December 2012 for all the scenarios (Banxico interest rate).

Scenario A is the scenario without the disease, so there aren't any citrus growers nor government expenditures on plant health strategies to control HLB. In scenario B, the losses caused by the bacterium are considered at a maximum level; according to Bassanezi et al (2008) there are several assumptions based on direct observations, such as: it is considered that only 30% of producers spontaneously adopt proper management and procedures to accomplish the Brazilian rule IN53, about eradicating plants at the indicated rate by the survey made by the Agency Fundecitrus (Belasque 2010). In the case of Mexico, Citrus growers have to accomplish the protocols on HLB control published in 2010 and 2012. Moreover, COEPLIM and CESAVECOL did a similar survey and they got the following numbers: 59% have a 15% incidence of HLB and they want to keep it this way, 33% have almost 50% incidence of affected trees in their groves and they do some investment to deal against HLB in their groves. Just 8% of the citrus producers are not applying any control at all, therefore they have more than 50% incidence of HLB. However, for simulation purposes, it will be stated in the model that between 26% and 30% of the citrus growers will have the economic power to deal with the strategy. The losses caused by the bacterium are considered at an assumed maximum level; considering that only 30% of Colima´s citrus producers spontaneously adopt proper management and procedures established by Protocols of control.

In scenarios C and D, since the strategies are kept for a 20-year projection, it is assumed that 3% of the trees are eliminated for reasons different of HLB besides the trees cut by the citrus producers under the eradication rates established by Bassanezi & Bassanezi (2008). Finally a 100% of the trees will be eliminated at the end of the 20 years period, when citrus growers are doing proper management of the grove and the disease. Thus, orchard productivity can be maintained at economically feasible levels. For scenario A since there is no disease. Nevertheless, a 3% annual replanting in the grove due to other reasons other than HLB is considered. The four scenarios assume that every 20 years the citrus growers renew the whole grove. In Table III.1, data about citrus trees in citrus areas was provided by COEPLIM and CESAVECOL in 2013, as well as about the incidence level of HLB in these zones for the same period. In Table 2, the number of plants per age in the state is observed; this was used for forecasting how the disease is progressing in the citrus groves.

Table III.1. Sample data about citrus trees in citrus areas established by COEPLIM and CESAVECOL, in 2013.

MODULE		GROUPS	% ADVANCE	(%) INCIDENCE	HAS	CITRUS TREES
1	Cerro de Ortega	2	33.16	2.4	155.75	32,270
2	Ahijadero Tecuanillo	1	13.08	2.31	1,912.50	406,914
3	Chanchopa Saucito	7	38.64	1.61	711.85	128,951
4	Cofradia Morelos	1	13.44	1.06	696.45	121,471
5	Tecuanillo Real	2	8.02	0.97	1,786.36	331,843
6	Tecolapa libramiento	6	21.65	0.86	709.9	142,617
7	Llano	1	20.44	0.77	964	200,512
8	Madrid	2	16.36	0.54	236	47,200
9	Caleras	5	28.44	4.47	359.22	80,687
10	Cuyutlán Paraíso	3	24.71	4.51	767	166,200
11	Periquillo Juarez	3	17.93	3.04	382.5	76,500
12	Coalatilla	4	6.53	7.71	441.75	88,350
12	Cofradía. Excaltitan	3	2.96	0.89	317.25	55,350
12B	Cofradía. Peña	1	51.69	3.74	297	54,945
13	Cofradía. Cañita	4	19.53	6.24	317	63,060
13B	Cofradía. Puertecito	3	17.34	0.59	212.1	35,547
14	Rincón	1	17.74	0.84	343.05	68,610
15	Pueblo Esperanza	5	28.71	0.99	448.33	86,302
16	Coquimatlán Colima	4	41.46	1.25	236.6	50,219
17	Reyes - Carranza	4	33.08	2.06	444.5	88,900
18	Colomo Charco	3	85.84	2.7	347.4	52,110

Source: Prepared with data from INEGI 2013, CESAVECOL AND COEPLIM 2013

The forecast of the incidence of the disease, in the long run uses information about age categories and group of age; trees can be classified as young, middle aged, or old and were identified by the technicians as with or without symptoms. So, the affected trees in the State were obtained with the given the information for the number of trees and the disease incidence level for all the modules. This information was also calculated based the work done by COEPLIM and CESAVECOL in 2012 (2013). The reports are available in the National Service for Plant Health, Safety and Agri-Food Quality (SENASICA) website (SENASICA 2015).

Table III.2. Sample data about citrus trees by ages category with data from INEGI CENSUS, COEPLIM and CESAVECOL, in 2013

Municipality	0-2.9 Years	3-5.9 Years	6-10 Years	> 10 Years	TOTAL
Armería	183,653	292,597	360,412	131,930	968,592
Colima	22,239	30,391	26,707	15,665	95,002
Comala	7,072	4,328	-	101	11,502
Coquimatlán	52,106	52,113	53,462	4,262	161,944
Cuauhtémoc	323	101	625	-	1,049
Ixtlahuacán	5,989	2,922	931	13,184	23,026
Manzanillo	36,320	60,384	62,838	14,825	174,366
Minatitlán		1,407			1,407
Tecomán	463,197	703,485	920,588	647,501	2,734,771
Total	770,898	1,147,728	1,425,562	827,468	4,171,657

Source: Prepared with data from INEGI 2013, CESAVECOL AND COEPLIM 2013

As mentioned earlier, the epidemiologic model is the one proposed by Bassanezi and Bassanezi (2008). This document is important because it gives a sense of the decrease in yield taking as reference the productivity of a healthy citrus tree. It is important to mention that, Bassanezi´s calculations (2008) are based on the observations of the Brazilian technicians from Fundecitrus, at the beginning of the infection and in their program built to calculate the progress of the disease. This latter is an excellent document of reference while projecting the progress of the infection. The number of diseased trees and the loss of productivity per each scenario take the region into consideration.

All the calculations are done taking into account the number of boxes produced annually. For this paper's purpose, the considered boxes are the standard 40 pound ones, managed commonly for limes. Another important assumption in Miranda's model (2010 and 2011), and also managed in Bassanezi's (2008), is defining the annual rates of replanting the grove. This rate can be a decision coming from the grower or it can be pushed by enforcement of public policy of eradication and replanting.

Another important input for the model is the database with the historic prices paid to the citrus grower in every harvesting season in Colima. The price frame provided is monthly prices from 2000 to 2012 (SNIIM 2014). According to Miranda (2011), data included in the model in this way allows to forecast prices during the 20 years time horizon and they include the overall movements of the market.

In all the scenarios, there weren't any government expenses considered, such as federal campaigns or programs intended to control and eradicate HLB. The main investment comes from the citrus producers 'own budget such as frequent insecticide pulverization, inspections, elimination of diseased plants from the groves and replanting of certified healthy citrus trees.

III.3. Results

Scenario A represents the production of key lime without HLB. Since this data was obtained just before the disease invaded the state completely, this could be the ideal or the hypothetical condition to accomplish once the disease is controlled. Scenario A is also the reference to compare scenarios B, with no control, C with no citrus trees eradication and just vector population control and D with eradication, vector control, citrus trees eradication and replanting. The graphs show the results in boxes as the units of production (Figure III.1).

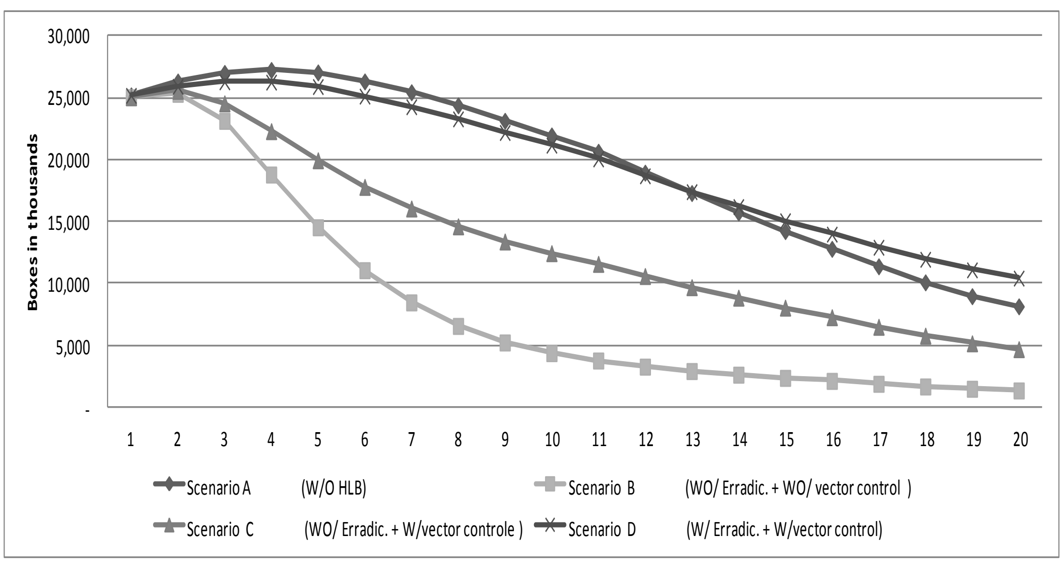

Figure III.1. Production observed after estimating the application of several scenarios to control HLB

It can be observed that scenario D, with presence of the disease and all the strategies applied, eventually can behave very similarly as scenario A.

Similar trends to figure III:1 can be observed in figure III.2, where instead of quantity, productivity and the value of production are expressing the same behavior in scenarios B, C and D.

After running the model and adjusting to the conditions of the State of Colima in Mexico, as other studies have already mentioned, it was confirmed that reduction in yield is the main cause for the economic losses caused by HLB (Figures III.1 and III.2).

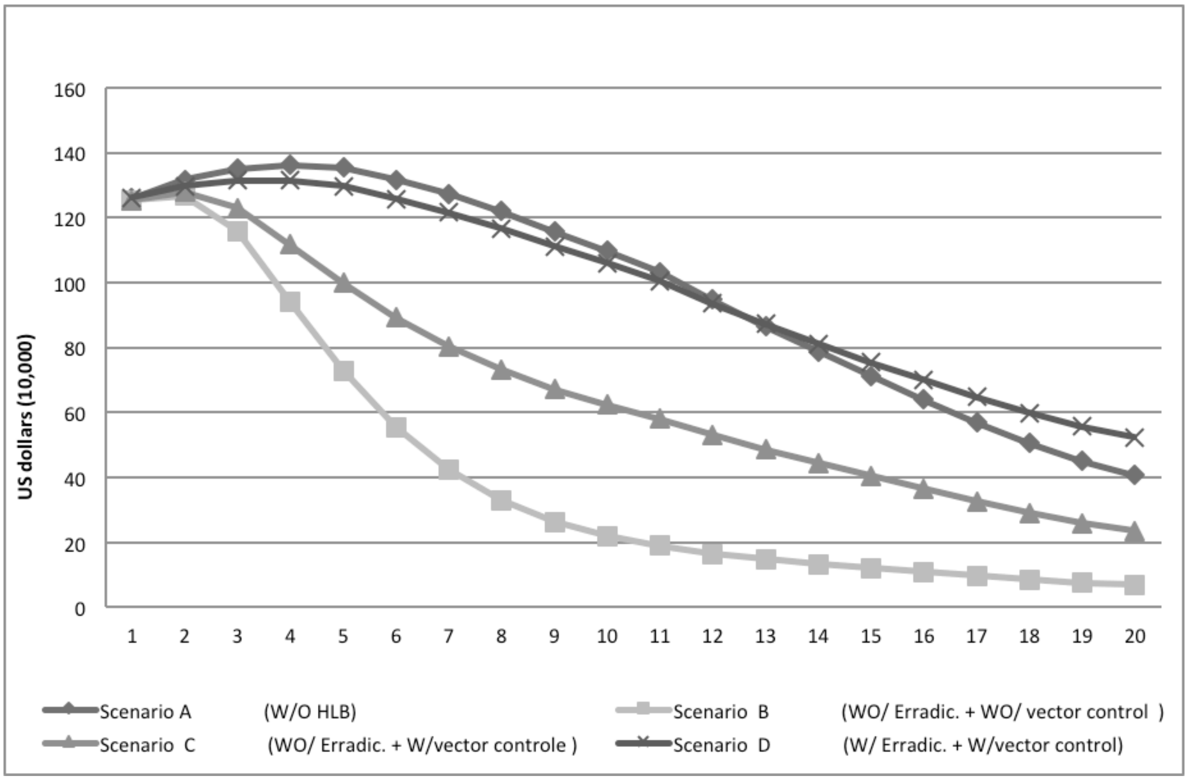

Figure III.2. Comparing value of production scenarios under several scenarios to control HLB

Scenario B is assumed with no insecticides application, no eradication of infected trees and no replanting. The behavior stated by Bassanezi (2008) according to his epidemiological model gives this dramatic loss in yield. The blue line corresponds to scenario C with application of insecticides but no eradication of infected citrus trees and no replanting. The Green line corresponds to scenario D, which includes application of insecticides, eradication of symptomatic citrus trees and replanting. Keeping good collaboration among citrus growers on good management practices leads to a strict control of the psyllid, and to a good control of the disease. Therefore, the citrus trees yield will behave in a similar way as a scenario without the presence of the disease.

Scenario C also shows that partial strategy application gives scenarios with partial control of the disease. This is because just the control of the psyllid is not enough to get rid of the infection. The high investment on frequent pulverizations does not increase production so the business declines for citrus growers not applying all the treatment. So, keeping decaying trees and investing on numerous pulverizations increases cost of production, in such a way that keeping the business is very difficult for most citrus producers.

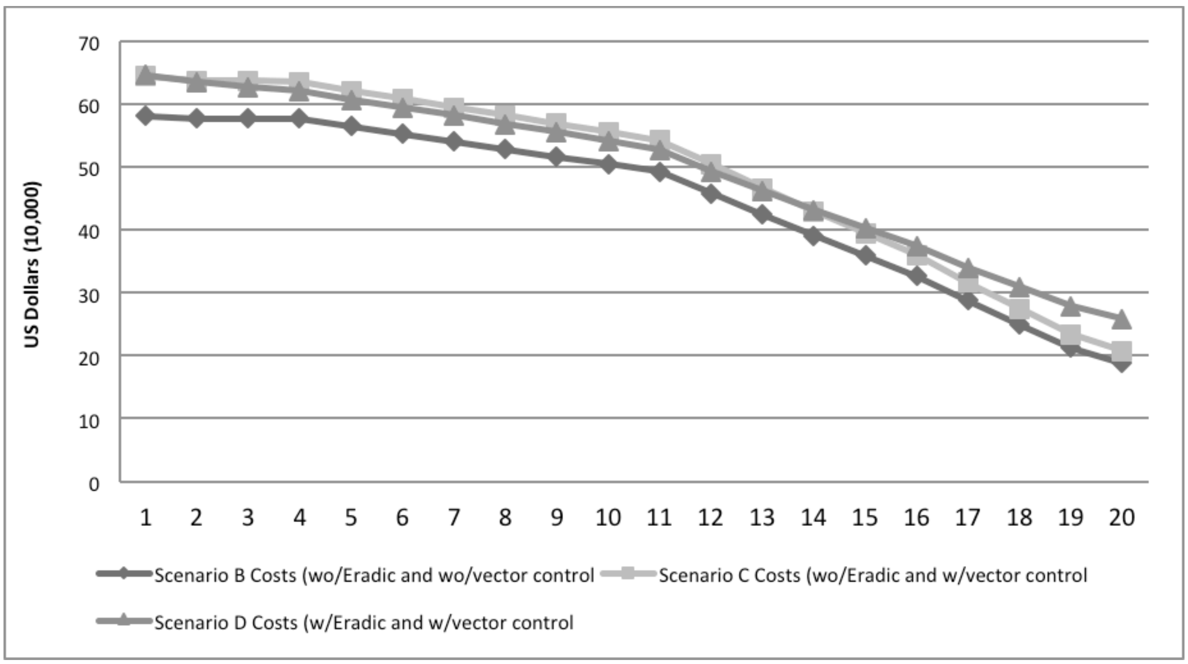

Figure III.3. Cost of production under scenarios B, C and D

In figure III.3, scenario B has the lowest costs because there is no eradication and no investment in vector control. Scenarios C and D are more expensive because scenario C increases the number of insecticide applications on an average of 10% more during the whole 20 years period. In scenario D the cost increases because of insecticides application for the reduction in population of psyllids, and replanting because of eradication of trees.

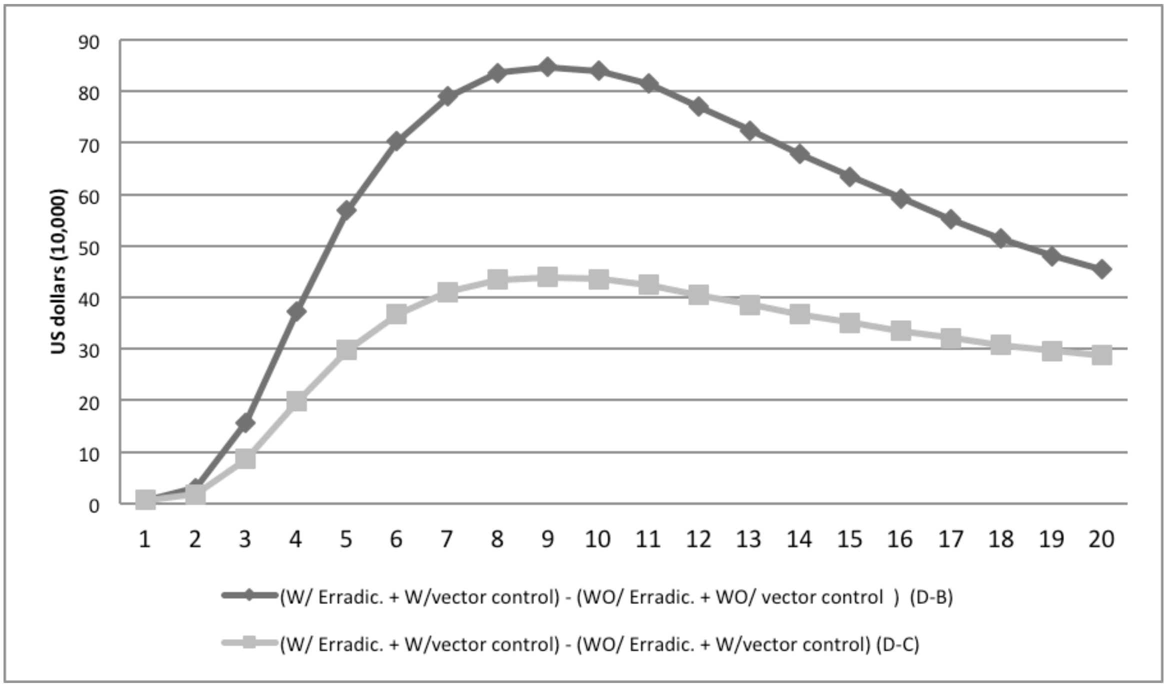

Figure III.4. Differences on benefits among scenarios considering value of production in dollars

In scenario D-B, the benefits of controlling the disease will be increasing at the beginning until the year nine and it is positive in all the time of simulation because new plantings increase production and income. This is because of the elimination of an important amount of diseased trees at the beginning of this first stage to control. However, over time, the orchard recovers profits on the basis of reduction in the rate of spread of the disease.

Differences among scenarios considering value of production are shown in figure III.4. If the program is adopted, losses in productivity are compensated while keeping healthy replanted citrus trees. The benefit of lowering the inoculum in the grove will be observed over time.

On the other hand scenario D-C will give fewer benefits because the strategies are just focused on controlling the vector population. The infected citrus trees will decrease production because of the disease and the profitability of the grove will diminish accordingly.

Table III.3. Results Summary and Net Present Value Calculations

Scenario B (WO/ Eradication + WO/ vector control)	
Years forecast	20.
Original Number of trees	4,171,656.
Lost trees because of disease	2,839,745
Production year 1 before detection	25,048,137
Lost Production after 20 years (Boxes)	23,695,402
Value of production year 1 detection US dollars	118,728,172
Production value in year 20	6,411,966.
Lost Value of Production after 20 years	112,316,207.
Removed plants because of greening	0.0
Scenario B Total Cost after 20 years	890,657,994.
Scenario C (WO/ Eradication + W/vector control)	
Years forecast	20.
Original Number of trees	4,171,656
Lost trees because of disease	2,839,745.
Production year 1 before detection	25,048,137
Lost Production after 20 years (Boxes)	20,358,106.
Value of production year 1 detection US dollars	118,728,172
Production value in year 20 ($)	22,230,749
Lost Value of Production after 20 years	96,497,423 7.
Removed plants because of greening	0
Scenario C Total Cost	980,558,486..
Scenario D (W/ Eradication + W/vector control)	
Years forecast	20.
Original Number of trees	4,171,656
Lost trees because of disease	2,502,635
Production year 1 before detection	25,192,036.
Lost Production after 20 years (Boxes)	14,759,473
Value of production year 1 detection US dollars	119,410,254
Production value in year 20	49,450,352
Lost Value of Production after 20 years	69,959,902
Removed plants because of greening	-1,182,500
Scenario D Total Cost	984,203,072
D-B Difference	
Production (Boxes)	227,445,532.
Removed plants because of greening	2,492,951

Benefit Cost ratio for Production Difference

Table III.3. Results Summary and Net Present Value Calculations

Production Benefit	1,078,091,824
Net Present Value Benefits	663,292,062
Production Costs	93,545,078.
NPV Costs	60,763,607.
Benefit Cost Ratio Producer	10.92
Sum total benefit coming from applying D-B	602,528,455.
D-C Difference	
Production (Boxes)	123,578,116
Removed plants because of greening	2,492,951
Benefit Cost Ratio for Production Difference	
Production Benefit	585,760,269
Net Present Value Benefits	356,957,641
Production Costs	3,644,585.
Net Present Value costs	-2,562,149
Benefit/ Cost Ratio Producer	-139.
Sum of total benefit coming from applying D-C	359,519,790.

Table III.3 shows the results on the calculations made in scenarios B, C, and D. Comparisons to Scenario A can be done on graph in figure IV.1. The model shows that D-B scenario production boxes are 227,445,532, and the Sum of total benefit coming from applying D-B obtained by the private investment made by citrus growers in the State of Colima per the whole stock of key lime trees is US $602,528,455/, after applying the whole strategies and constantly eradicating, replanting and pulverizing insecticides to keep the vector population controlled. On the other hand, the benefit cost ratio is US $10.91, which is positive and supports the viability of the decision of eradicating, replanting and pulverizing. Looking at other references about the advantages of applying scenario D to cover up scenario B is a production benefit of US $1,078,091,824.

Scenario D-C production boxes are 123,578,116 almost half of production obtained in scenario D-B. The benefit cost ratio obtained is -139. Therefore, it is negative, so the decision of just pulverizing insecticides without eradicating and replanting is not financially and economically viable after applying the whole strategies and constantly eradicating, replanting and pulverizing insecticides to keep the vector population controlled. In the other hand, the Sum of total benefit coming from applying D-C is US $359,519,790, which is way lower than D-B so this numbers supports the viability of the encouraging citrus producers to prefer D-B decision. Other measurements about the advantages of applying scenario D to cover up scenario B instead of C are a production benefit of US $585,760,269, almost half of the amount given by D-B.

III.4. Conclusions

Comparing all the results of scenarios applying strategies that deal with HLB to Scenario A of no disease, it is evident that the strategies involved in scenario D lead to the original yield before HLB but with more investment. Comparing with the scenario of no control at all (B), it is noticeable there are many losses that can be avoided. When citrus producers are not eradicating, the loss in productivity will decline rapidly. This analysis confirms that in three years, losses could be very high.

After applying the complete set of strategies stated for scenario D, the resulting yield is due to a result on reduction of the severity of symptoms exposed on well-maintained plants. If the grower spends money on controlling and eradicating, they are investing in future health conditions of the grove as the benefit cost analysis shows.

The benefit-cost ratio of plant health activities to control HLB assesses several scenarios (A-B-C-D) deciding how suitable they are to Colima's citrus groves. Scenario A is stated as production without disease. Scenario B is assuming spread of the disease without any control. Scenarios C and D establish intermediate situations between controlling and eradicating. Productivity depends on levels of incidence of the disease. Costs come from activities related to growing citrus and controlling pests. The BC ratio comparing Scenarios D-B establishes that for every dollar invested on the complete set of strategies, the return is 10.9, and NPV is US$663,292,061 for benefits and US $60,763,607 on costs. Comparing Scenarios the BCR D-C is -139, with NPV of US $356,957,641 on benefits and NPV of US $2,562,148.811 on Costs; therefore the feasible choice is D-B. Therefore, the private investment by the grower benefits the continuity in the citrus production in the long run. There are higher costs in scenario D at the beginning and as time goes by, costs will be decreasing steadily until the vector (Asian Citrus Psyllid) population is controlled and the inoculum is reduced.

Benefits from collaboration are seen as the success in the control of the vector population and consequently the spread of the disease. However, the bad neighbor effect is the key hindrance to vector control because spreading insecticides jointly by all growers may be the most important measure to control HLB that should be taken. This means scenario B, with no control of HLB, would be the one that would prevail eventually if there were no way to coordinate the interested citrus growers.

As stated by COEPLIM and CESAVECOL, most of the citrus growers in Colima have just implemented the pulverization of insecticides program but not adopted the regular eradication of plants with HLB symptoms, which is the other key measure to ensure disease control. As seen in figure 1, the benefits of the strategy cannot be seen if trees are not removed. Eradication of diseased trees still represents a productive immediate loss of income while representing high expenses in workers' need to do frequent inspection of the citrus grove and all the expenditures on removing and replanting.

Scenario D has several advantages over scenarios B and C. The first one is keeping production steady. The benefits are considered avoided loses therefore, they pay off the investment on eradicating and replanting, besides vector control. This means citrus groves have to be organized in strategic regions to obtain the benefits of the Brazilian approach.

The benefit cost ratio obtained from this analysis may be considered feasible in other producing states in Mexico, such as Michoacan, Guerrero and Oaxaca. These states' status is still not as infected by HLB as Colima. Thus, it is very important to take into consideration that the three-pronged strategy is mainly a preventive measure especially during early stages of the disease or in low levels of incidence.

The three-pronged strategy has to be applied in full to work, because applying one or two prongs do not allow a control of the vector and therefore doesn’t allow control of the disease.

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Capítulo IV. Economic Assessment of two managerial strategies for HLB resistant plants in Persian lime representative groves in the Mexican State of Veracruz under 2012 Scenario

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Abstract

This paper's purpose is to assess the economic viability (economic, financial and net cash flow) for two agricultural management strategies to control Huanglongbing (HLB) in Persian Lime Representative Production Units (URP) in the Municipality of Martinez de la Torre. The panel's technique was used to build URPs with 26 citrus growers' collaboration. They gave all the key technical and financial information to calculate production costs, net income, total income and breakeven prices. VRLP3.5 URP was selected to model the two scenario strategies for managing HLB through improved varieties and use of a vaccine. Under the conventional scenario the URP got a positive net income, under financial, net cash flow and economic production costs. The breakeven prices are covered by the selling price in the estimated optimistic, pessimistic and most likely yield scenario. The URP will be in business safely, for the short run, and very likely for the long run. The average yields per hectare in diseased citrus are estimated 40% less than the healthy orchards: Planting improved varieties and the vaccine are able to recover the loss in average yields in about a year according to researchers from IPN. In both managerial strategies for controlling HLB, the increase in costs does not compensate the increase in yields. Net income is just positive applying financial costs. Breakeven prices are not covered at all applying the vaccine against HLB strategy. Adopting either the improved varieties or the vaccine strategies are uncertain. To encourage the strategies implementation among producers, adopting a foster program with financial assistance for growers to pay the uncovered costs is required.

Key words: Vaccines, resistant plants against HLB, production cost, net income, Persian lime.

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IV.1. Introduction

Mexican Persian lime production began in 1983 (Espinosa, 1993) but it was until the 1990's when it started to consolidate as an important economic activity in the country (INFOASERCA, 1996, Schwentesius, 2005). Initially production was intended to the export market, mainly the US, but lately it gained its share into the domestic market. The Persian lime market got into very fast dynamics in the last decade (2002-2012). The cultivated area increased 2.2 times from 24,573 to 78,504 hectares and production went up 256% (SIAP 2013). Persian lime has gained market share because of the opening of the domestic markets due to commercial promotion, According to the Mexican ministry of Agriculture (SAGARPA 2013) Persian lime prices increased 10% from 2010 to 2012. It is also considered an attractive business choice by the decision maker's inserted in the production and commercialization businesses because Persian lime created an agricultural GDP of 2,227 million pesos. The Mexican state of Veracruz contributed to this Agricultural GDP with 67% or 1,483 million pesos (SIAP, 2013). Persian key lime is produced the whole year with 3 clear seasons: January to April with low production and high Price, April to July with high production and low price and finally July to January with moderate production and moderate price.

On the other hand, representative farms and the panel's technique have been used all around the world with the purpose of presenting the economic status on agricultural activities. The International Farm Comparison Network (IFCN) on charge of Doctor Torsten Hemme *et a*l is gathering information on the dairy industry. Every year, since 2000, they present the "Overview on milk prices and production costs world wide". Researchers in Universities all around the world contribute to build this document which analyses dairy production. The ministry of Agriculture in Mexico has been working with citrus production costs using national averages. Sagarnaga *et al.* (2000; 2006, 2011) assessed the profitability and economic viability for swine representative farms using the panel's technique with the support of researchers from the Agri Food Policy Center (AFPC) at Texas A&M University. Richardson et al (2008) at AFPC from TAMU maintain the representative farms network, which is a database registering agricultural operations representing the major agricultural production regions in the US. These operations are used in economy and policy research analysis. The representative farms are updated every two years using face to face panel interviews. Types of operations include cotton, rice, feed grain, and wheat farms, cattle ranches, and dairy. Richardson et al also collaborated with the Mexican ministry of Agriculture to create the first effort in building representative farms with the purpose of giving the decision makers unbiased and objective economic analysis of the impacts for policy alternatives. Agricultural operations started in this first trial were corn, wheat, bean rice, key lime, apple, peach, pecan, cotton, tomato, cucumber, coffee and avocado. Other operations integrated to the model were fisheries, diary and cattle ranches (Richardson *et al.*, 2000, AFPC, 2012).

This research problem starts when in 2010 an outbreak of greening (HLB) is detected on citrus in the Mexican state of Yucatan. HLB is the most harmful disease worldwide detected in citrus in the last century (orange, key lime, grapefruit, mandarin, tangerine) HLB clogs the tree's vascular system and it eventually dies because of lack of nutrition in about 5 years. Fruits have modified shape, partial ripeness, and decrease of sweetness (Bové, 2006, Gottwald, 2007, 2010). Besides the death of the tree during the process of vascular system clogging, the yield is diminishing progressively. Flowers and immature fruit are dropping before the expected dates on healthy trees. So, losses on diminished yields are up to 20% (Bové, 2006).

Citrus Growers in the US pushed researchers to think of a solution because of the dramatic increase of diseased trees in Florida, California and Texas. In 2012, Researchers at the Agrilife Research Institute in Texas A&M offered a genetically modified variety which possess a spinach transgenic gene. Other institutions working with transgenic citrus are University of Florida and the Sylvio Moreira Citrus center in Sao Paolo, Brazil. Besides these institutions, in Mexico the Research and Advance Studies Center (CINVESTAV) from the National Polytechnic Institute has been spreading among the citrus decision takers the use of gene engineered citrus introducing the desirable characteristic of resistance against Liberibacter sp without endangering the citrus quality, neither fruit nor flowers. The other option created by researchers from CINVESTAV is creating acquired systematic resistance by applying a vaccine to the tree and activating the tree's overall immune system. This immune system response will reduce the disease symptoms and eventually the tree recovers from the infection to normal yield.

The Mexican state of Veracruz is the main producer of the Persian lime and so far in May 2014 there is no official report from the Food safety and agrifood quality service (SENASICA) about infected citrus with HLB. Therefore this state is an ex ante HLB free scenery where preventive measures should be preferred as part of the control before a major HLB devastation on the citrus groves within the state. Therefore, this work's hypothesis is preventive managerial decisions improve the Persian lime URP economic feasibility. Therefore, the main objective is to assess the feasibility under economic, financial and net cash flow cost scenarios for establishing two managerial strategies for preventing HLB on Persian lime Representative Production Units (URP) from Martinez de la Torre Veracruz. Particular objectives are 1) Estimating the costs of production (economic, financial and net cash flow) net income, total income for a traditional orchard, an orchard adopting 30% of transgenic resistant citrus and an orchard adopting a vaccine against HLB in 100% of the surface. 2)·Estimating breakeven prices for most likely yield and under pessimistic and optimistic yield expectation for traditional, 30% resistant plants and on vaccine treatment orchards

IV.2. Methodology

This job began with the establishment of 4 URPs during July 2013 under the Project "Production Costs for strategic products in the Mexican humid tropic area" supported by the Ministry of Agriculture SAGARPA. The URPs built for Persian lime production costs purpose are located in the municipality of Martinez de la Torre Veracruz, the main producing region in the state and the country. The panel's technique was used to build four URPs with the collaboration of 26 citrus growers. They gave all the key technical and financial information to calculate production costs, net income, total income and breakeven prices under consensus. VRLP3.5 URP was selected to model the two scenarios strategies for managing HLB through improved varieties and using a vaccine. All the growers were selected based on their involvement in the Persian lime organization and meetings about phytosanitary issues and commercialization. Representative farms were established under growers' empirical knowledge. The URPs are also designed under an assumed scale, technology, production systems and intended market given by the producers' consensus. All these URP are HLB free and the preventive measures are assumed to control those similar HLB effects observed on Mexican lime or key lime.

The given information from the entire panel`s process was evaluated to calculate costs of financial production, economic and net cash valued for the year established as baseline (2112). Later a second visit was done to validate the calculated costs. They were presented to the same producers. The analysis was based on the following assumptions 1) scale of production, installed capacity and technological level are constant, 2) the number of producers involved in Persian lime production stays the same, 3) improved varieties introduction implies to increase cultural costs, fertilization and pesticides spreading are about 30%, and 4) the use of a vaccine per tree requires to spend the money to buy the necessary amount for covering the whole plantation and to pay the necessary labor to apply the vaccine on each tree. Taking all the conditions described below into consideration, the results gave the information about the economic feasibility for every URP on baseline year 2012.

Information obtained through the panel's technique was captured in a pro-forma. All the gathered information was adjusted to the actual and representative information required to reproduce the operations represented by the size and characteristics stated by consensus in each URP. Pro-forma is one of the statements used in basic accounting and gathers all the information about family expenses, assets, debts, costs, and depreciation in the previous year (t-1). Year t-1 is used as the basis to calculate the current year (t) (Richardson & Outlaw, 2008). This Pro-forma also gathers information about variable and fixed costs, opportunity costs and expected prices on the product, main supplies, and citrus yields in tons per year sent to the market.

Once the proper adjustments were done, according to Willet (2013) and economic theory, variable costs (VC), fixed costs (FC), economic costs (ECC)) were calculated, these costs include all cost attributed to all resources, including purchased inputs, equity capital, and operator/family labor and management. Financial costs (FINC) were also calculated taking in consideration all cost attributed to all resources, except equity capital and operator/family labor and management and finally cash expenditures (FNE) were calculated including only cash expenditures are considered, including principal and interest on term debt and personal withdrawals. Depreciation and interest on equity are excluded for the last. The total cost (TC) was calculated adding CF+CV. All separated incomes such as selling Persian lime under different qualities plus income obtained from transfers are added to calculate total income (TI). Net income (IN) is obtained from subtracting TC from TI.

Breakeven price is the price needed to cover all costs as defined according to financial accounting (tax and financial statement reporting) standards. It implies zero return to operator/family labor, management, and equity capital Therefore, breakeven prices are those required to cover ECC, FINC and FNE under different production scenarios and they are calculated dividing total cost TC over probable yields under optimistic, pessimistic and the most probable conditions. Calculations are made with the following formulas:

a) Breakeven price required to cover all economic costs under the most probable yield

$$\sum ECC/\ Y1 \qquad (1)$$

Where CE: Economic cost Y1: yields under the most probable scenario

b) Breakeven Price required to cover all economic costs under the optimistic yield scenario

$$\sum ECC/\ Y2 \qquad (2)$$

Where CE: Economic cost Y: yields under the optimistic scenario

c) Breakeven price required to cover all economic costs under the pessimistic yield scenario

$$\sum ECC/\ Y3 \qquad (3)$$

Where CE: Economic cost Y3: yields under the pessimistic scenario

Same procedure is used to calculate breakeven prices for financial costs and net cash flow costs.

Pricing Objectives

These prices are those intended to cover financial, economic and net cash flow cost of production per each URP. It was used the methodology of Willet to calculate them.

a) Price required covering just the variable cost (P1)

Minimum price (P1) required by the producers covering their short run obligations. If the selling price falls shorter than this, URP should stop production process because it will not be able to obtain fresh external resources to keep in business.

$$CVDU = \sum CVD / Y \tag{4}$$

Where: CVDU Unit Variable Cost withdrawal; CVD variables Costs withdrawal y Y: yields under the most probable scenario.

Test P1 >=< CVDU. If PCVD>, then URP will be able to cover variable costs withdrawal, if <, URP will not be able to cover variable costs withdrawal.

b) Required Price to cover variable and fixed costs withdrawal (P2)

Obtaining this price (P2) the producers can cover variable and fixed costs meant being paid in cash.

$$CTDU = CVDU + (CFD/Y) \tag{5}$$

Where: CTDU: Unit Total Variable Cost withdrawal; CFD: Fixed Costs withdrawal, y Y: yields obtained by the most likely scenario.

Where P2 >=< CTDU. If >, then URP will be able of covering unit total cost withdrawal; If <, URP will not be able of covering the unit withdrawal cost.

c) Required Price to cover all the net cash flow obligations including payments to capital and producer withdrawals (P3). Obtaining this price (P3) producers can cover all the URP obligations in cash and so partial payments on long term credits and producer withdrawals (personal and family expenses)

$$GTDU = CTDU + ((PP+RPF) / Y) \tag{6}$$

Where: GTDU: unit total expenses withdrawal; PP: Payments to capital y RPF: family and producer withdrawals.

Test P3 >=< GTDU. Si >, then URP will be able to pay unit total expenses withdrawal; if <, URP will not be able to cover unit total expenses withdrawal.

d) Required Price to cover variable and fixed costs in cash (excluding payments to capital and producer withdrawals) and fixed costs with no withdrawal (P4). Difference with last price is that obtaining this price (P4) the URP can cover all the financial obligations withdrawal or not including depreciation, not including payments to capital and producer withdrawals.

CTFU = CTDU + (CTND/Y) (7)

Where: CTFU: Unit Total financial cost withdrawal; CTND: Total Costs with no withdrawal, y Y: yields obtained by the most likely scenario.

Where P4 >=< CTFU. If >, then URP will be able of covering all financial cost; If <, URP will not be able of covering the total financial cost in liquidity order.

e) Price required to cover all the payments in cash, fixed costs with no withdrawal, the family and producer labor with no wages, administration, and contribution to net capital investment (labor net capital, land, infrastructure, machinery and equipment) (P5).

CTEU = CTFU + (MONR + CGE + RCNI / Y) (8)

Where: CTEU: unit total economic cost; MONR: producer and family labor cost with no wages payment; CGE: Administration Cost y, RCNI: Return to net capital investment.

Test P5 >=< CTEU. if >, then URP will be able to pay the total unit financial cost, opportunity cost (used resources, and return to the risk taken by the producer, if =, URP will be able to cover the total economic cost without paying the risk. If <, URP will not be able to cover the total unit economic cost.

IV.3. Results and Discussion

URPs built by small producers have a surface in between 1 to 5 hectares. They are used to plant crossbreed varieties. Operations are performed manually because of lack of machinery and other agricultural supplies. However, these conditions are allowing them to meet a very high quality not only for the domestic but also for the exports Persian lime market. URP built by medium size producers is about 20 hectares surface. The producer is more aware of trying to maximize profit-reducing costs by using specialized equipment and machinery, but the quality of the harvested product lessens in between high and medium. URP built by large producers is about 200 hectares or more. This URP counts with machinery, own packing facilities, specialized equipment and a technical consultant. This URP is the most profitable; however, it is the one with the least product quality for the Persian lime fresh market. Most of its product goes to the juice industry.

All the producers participants in the URPs claimed to invest strongly in fertilizers and pesticides. They may apply them combined and accordingly with the month of the year (Table IV.1 and IV.2). The most important cost for all the URPs is the harvest because most of them pay the labor to make it manually, overall, when they want to sell to the fresh market. This operation requires of experienced harvesters because the higher of the price depends on the quality of the product.

Table IV.1. URP Characteristics

URP	Surface (ha)	Assets Value (1,000)	Total Income (1,000)	Persian lime Income /Total income (%)
VRLP01	1	62.68	56.25	100
VRLP3.5	3.5	91.50	224.00	100
VRLP20	20	374.47	1,329.65	100
VRLP200	200	1,594.47	12,170.4	100

Source: Data gathered from fieldwork

URP denominated VRLP20 has the best yield because of higher plants density, use of specialized machinery and medium to high quality of the product harvested (Table IV.2). It is important to make the reader aware that all the technical parameters and yields presented so far are under HLB free conditions. The Mexican state of Veracruz has not had a report of presence of HLB on citrus until May 2014.

Table IV.2. Technical Parameters

URP	Plant Density	Yields ton/ha Without HLB	Estimated yield with ton/ha Con HLB (40% reduction)	Total Production (ton)	% Mechanization (*)	Number of workers and harvesters per ha
VRLP01	500	13	7.8	12,750	50	106
VRLP3.5	260	15	9.6	16,200	65	200
VRLP20	357	25	15	25,375	70	150
VRLP200	200	22	13.2	22,000	90	100

Source: Data gathered from fieldwork
(*) One operator/ one machine or specialized equipment used in agricultural activities

Under the 2012 economic scenario the 4 URP built are profitable considering just to cover financial costs. It is important to mention that those economic conditions include also phytosanitary and technical conditions for the four citrus groves. VRLP200 is the one with the least production costs per kg produced (Table IV.3). It is important to remember that this scenery is without HLB influence.

Table IV.3. Main financial variables, baseline 2012 ($)

URP	Total cost /ha (1,000)	Cost /kg	Net income /ha (1,000)	Net Income /kg
VRLP01	22.96	1.80	56.25	4.41
VRLP3.5	33.41	2.08	64.00	4.00
VRLP20	32.58	1.28	66.48	2.62
VRLP200	22.85	1.03	60.85	2.76

Source: Data gathered from fieldwork

All the stated so far is the basement information to establish how Persian lime producers are producing in a conventional scenario freed of HLB. In order to estimate how HLB would affect Persian lime growers it was taken as reference all the information about HLB affecting key lime producers in the Mexican State of Colima. It was assumed a yield reduction about 40% according to producers in Colima (SENASICA 2012).

Comparative Analyses taken in consideration improved varieties and the use of a vaccine.

Taken in consideration the information obtained from the four analyzed URPs, VRLP was chosen because is the most frequently found within the region. The income obtained makes it profitable but not able to make decisions in big investments but is the one that produces the highest quality. All the calculations presented above were adjusted to fit a scenario of presence of HLB. The main changes were changes in costs derived of the acquisition of an improved variety or the planting of a HLB resistant variety and the other scenario assuming a complete infection of HLB, reduced 40% yields and acquisition of a vaccine for the whole grove. Under these new conditions two more assumed URP were created: VRLP3.5M and VRLP3.5V.

Conventional VRLP3.5

This is the original 8-year-old URP freed of HLB. It has a total surface of 3.5 hectares, produces Persian lime on Swingle rootstock, owned by commons and watered by weather conditions. It has a plantation density of 260 trees per hectare. It is considered a medium technical level because of the use of fertilizers, pesticides and frequent cuts during the year. The producer harvests and commercializes the product accordingly to the season of the year. The whole production is commercialized by auction.

Total income VRLP 3.5

Growers participating in the panel said during the interview that they do not receive transfers. They do not produce secondary products. They established their income is obtained in a 100% from the Persian lime production and selling. The estimated yield is 16 ton by hectare. They estimate 50% of the fruit is first quality or export quality. 25% is second quality or domestic market quality and the last 255 is third quality or juice industry quality. The calculated total income is 64,000 pesos/hectare (Table IV.4).

Table IV.4. Total Income VRLP3.5

Concept	Economic (1,000)	Financial (1,000)	Cash Expenditures (1,000)
Principal Product	64.00	64.00	64.00
Secondary Products			
Total Income	64.00	64.00	64.00

Source: Data gathered from field work

Production costs VRLP3.5

The main cost is the specialized harvesters hired during the year. The amount spent under this concept is $17,400 pesos. This cost would be paid by the producer in case he is not able to harvest by himself or his family. The producer would be willing to pay this amount because harvesting is the most critical point in all the train of production and it is the one that determines the expected price for the product. The highest fixed cost is depreciation because this URP uses some machinery to transport the product out of the orchard to the packing station and from there to the auction. This cost is up to 5,601 pesos per year. This concept is not considered as part of the net cash flow costs, it is just part of the economic and financial costs of production. In the matter of opportunity costs, administration is the most expensive; this cost is about compensating the people in charge of the management of the business and all the administrative issues in the orchard. The opportunity costs grand c total is up to 23,431 pesos per year. In the matter of "other costs" the main cost is the one attributed to the producer's withdrawals; they are up to 20,800 pesos per year (Table IV.5).

Table IV.5. Total Costs ($) VRLP3.5

Concept	Economic (1,000)	Financial (1,000)	Cash Expenditures (1,000)
Variables costs			
Fertilizers	2.39	2.39	2.39
Pesticides	0.68	0.68	0.68
Gasoline & lube	3.04	3.04	3.04
Tools	2.00	2.00	2.00
Insurance	0.0	0.0	0.0
Maintenance & repairs	1.00	1.00	1.00
Hired labor	17.40	17.40	17.40
Other expenditures			
Total variables costs	26.51	26.51	26.51
Fixed Costs			
Interest rate	0	0	0
Depreciation	5.60	5.60	0
Taxes	0.293	0.293	0.293
Services	0.773	0.773	0.773
Other fixed costs	0.240	0.240	0.240
Total fixed costs	6.90	6.90	1.30
Opportunity Costs			
Land investment	9.60	0	0
Machinery & buildings investment	0.15	0	0
Cost on labor capital	2.12	0	0
Family labor	0	0	0
Administration	13.68	0	0
Total opportunity costs	23.43	0	0
Other costs			
Partial payments on long term debt	0	0	0

Concept	Economic (1,000)	Financial (1,000)	Cash Expenditures (1,000)
Producer withdrawals	0	0	20.80
Total other costs	0	0	20.80
Total Costs			
Per hectare	56.85	33.42	48.61
Per ton	3.32	1.95	2.84

Source: Data gathered from field work

The economic production cost is 3.32 pesos per kg and remunerates all the used resources for production purposes including supplies, interest rate payment for net capital investment, payment for hired labor, including family labor, and administration. In the matter of financial cost, this is 1.95 pesos per kg and includes all the used resources for production purposes excluding interest rate payment for net capital investment, payment for family labor, and administration. Finally, the net cash flow cost of production is 2.84 per kg, and reimburses all the costs paid in cash including credit payments (capital and interests) and also the producer withdrawals and family expenses. This cost does not include depreciation refunds nor interest payments on net capital investment (Table IV.5).

Net income VRLP3.5

Net income was found taking total costs from the total income and it is up to 7,150 pesos per year taking just all the economic cost of production. Net income is up to $30,580 pesos when it is subtracted just the financial cost of production and net income is up to 15,380 pesos when it is subtracted the net cash flow cost of production (Table IV.6).

Table IV.6. Total net Income ($) VRLP3.5

Concept	Economic (1,000)	Financial (1,000)	Cash Expenditures (1,000)
Net Income	7.15	30.58	15.38

Source: Data gathered from field work

Production costs VRLP3.5M

As it was stated earlier the first analyzed scenario is the one with the introduction of an improved variety resistant to HLB as a preventive measure. VRLP3.5M has exactly the same production characteristics as VRLP3.5 but in this one it is assumed it already got all the HLB effects and it needs to combat the disease. Several processes are assumed to have this scenario ready. First of all 30% from the original orchard must be cut for a first stage of introduction and for not putting the orchard out of business. HLB Resistant plants will be planted in this freed area keeping the original grove density of 260 trees per hectare. It is assumed that all the new trees come from a certified nursery green house and they have the modified gene graft to resist HLB. The plants are also certified as free of Canker, leprosies and Citrus Tristeza Virus CTV. The cultivated terrain was prepared exactly the same as the original process for the conventional orchard. Therefore, the normal yield of 16 tons per year will be accomplished in about two years depending on the orchard management. It is required to invest in the same herbicides, watering systems, phytosanitary controls just in the same way as the rest of the orchard in original conditions. Also the costs of trimming and shaping are assumed the same. The cost per each of the improved plants is 38 pesos per plant. (Table IV.7).

Table IV.7 Replanting costs for 1.16 hectares with an improved variety VRLP3.5M

Concept	Cost per unit ($)
Trees/ha (Units)	292
Cost / trees ($/unit)	38
Cost of plants ($/ha) (30% orchard = 1 ha)	11,096
Planting Cost ($/plant)	1,500
Fertilizers ($/ha)	1,454
Fertilizers ($/ha) labor	478
Herbicides ($/ha)	8
Herbicides ($/ha) (labor)	1,200
Insecticides ($/ha)	760
Other chemicals ($/ha)	700
Other costs ($/ha) mechanical activities	3,000
Total	20,083

Source: Data gathered from field work

The main change in the variable costs VC is the one attributed to the acquisition if the improved plants, this cost is calculated in 11,093 pesos, another important cost is the hired labor for planting the improved varieties at a cost of 4,716 pesos per hectare. Therefore, the total investment for planting a 30% of the orchard with brand new improved varieties is $20,233 pesos per 1.16 hectare. Considering this scenario the rest of the costs also diminish in a 30%. Therefore, the total variable cost for VRLP3.5M is assumed to be 38,416 pesos (Table IV.8).

Table IV.8. Variable Costs ($) VRLP3.5M

Concept	Economic (1,000)	Financial (1,000)	Cash Expenditures (1,000)
Fertilizers	3.17	3.17	3.17
Pesticides	0.40	0.40	0.40
Gasoline & lub	1.82	1.82	1.82
Tools	1.20	1.20	1.20
Insurance	0	0	0
Maintenance & y repairs	0.60	0.60	0.60
Hired labor	10.98	10,98	10.98
Other expenses	20.23	20.23	20.23
Total variable costs	38.41	38.41	38.41

Source: Data gathered from fieldwork

Fixed costs CF and opportunity costs COp are not affected by the decision of introducing improved varieties because the same fixed assets are used and the services paid are exactly the same. It is not required a new investment in fixed assets.

Under this scenario resulting total financial costs increased to 42,200, total cash flow costs to 59,900, and total economic costs increased to 58,690 pesos per hectare a year. These are increments between 3 and 27 percent compared with the conventional VRLP3.5 (Table IV.9).

Table IV.9. Total Costs ($) VRLP3.5M

Concept	Economic (1,000)	Financial (1,000)	Cash Expenditures (1,000)
Total Cost per hectare	58.69	42.20	59.99
Production Cost per ton	3.68	2.63	3.75
Increase (%)	3	27	24

Source: Data gathered from field work

It was taken the yield of 16 ton per hectare for estimating the income for the first year of introducing the improved varieties. The yield keeps its level in the 70% of the orchard but drops dramatically in the 30% with the new variety. Therefore it was assumed a new average yield for the orchard of 10.5 tons under the most probable scenario (Table IV.10). It is also assumed that low yields will be kept just in the first or second year after planting the improved variety. Yields would recover as soon as the new plants are developing and flushing as the rest of the orchard.

Table IV.10. Yields under different scenarios (t) VRLP3.5M

Concept	Most probable	Optimistic	Pessimistic
t/month/ha	10.5	19.6	3.5

Source: Data gathered from field work

Net income VRLP3.5M

Net income was found taking total costs from the total income and it is up to 7,150 pesos per year

The net income IN is positive and up to 2590 taking in consideration just financial costs of production. NI is negative when economic and cash flow costs of production are taken into account. Loses are calculated in 13890 and 15190 respectively (Table IV.11)

Table IV.11. Net Income a URP ($) VRLP3.5M

Concept	Economic (1,000)	Financial (1,000)	Cash Expenditures (1,000)
Net income	-13.89	2.64	-15.19

Source: Data gathered from field work

Production costs VRLP3.5V

Here the grove runs on conventional varieties but it is assumed that they become affected by HLB, then the acquisition of the vaccine makes the trees to recover from the infection regaining productivity until the yield is 16 ton / hectare again. VRLP3.5V has higher production costs because of the acquisition of the vaccine and the hiring of the workers trained to apply the vaccine to the tree. The vaccine is applied to every tree into the whole orchard. The estimated cost of the shot of the vaccine applied once a year is $38 pesos according to researchers from CINVESTAV. Variable costs of fertilizers and pesticides remain the same. Under this scenario, hired labor increases to $18,043 pesos per hectare, because this cost now includes the people hired to apply the vaccine. These people work in brigades to inoculate 20 trees per day per worker.CV are also increased because of the annual acquisition of the vaccine for the whole orchard. According to researchers from IPN-CINVESTAV this cost is about 38 pesos per tree. This cost multiplied by the 260 trees per hectare gives a cost of 10,260 pesos per hectare plus the hired labor. Fixed costs CF do not increase because it is not necessary to acquire any kind of asset. There is not also change in opportunity costs neither in other kind of costs. The increase in financial costs because of the acquisition of the vaccine and its application directly into the grove is about 39%, considering economic production costs the increase is about 27% and for cash flow production costs the increase is almost 30% (Table IV.12).

Table IV.12. Total Costs ($) including the use of vaccine VRLP3.5V

Concept	Economic	Financial	Cash Expenditures
Variables Costs			
Fertilizers	2,391	2,391	2,391
Pesticides	680	680	680
Gasoline & lube	3040	3040	3040
Tools	2000	2000	2000
Insurance	0	0	0
Maintenance y repairs	1000	1000	1000
Hired labor	18,043	18,0423	18,043
Other expenditures	10,260	10,260	10,260
Total variables costs	37,414	37,414	37,414
Total Costs Per hectare	67,752	44,321	59520
Per ton	4,234	2,770	3,720
Per kilogram	4.23	2.77	3.72
Increase (%)	19	33	22

Source: Data gathered from field work

Yields VRLP3.5V

Once affected with HLB, citrus trees usually diminish their productivity down to 40% (Gottwald, 2010), which means yields may go from 16 to 9.6 ton per hectare. Once the vaccine is applied, citrus trees develop resistance against HLB and yields may recover the usual rate, Yields considered in this scenario are 9.6 ton per hectare for the first year of vaccine treatment (Table IV.13).

Table IV.13. Yields under different scenarios (t) VRLP3.5V

Concept	Most likely	Optimistic	Pessimistic
t/month/ha	9.6	19.6	3.5

Source: Data gathered from field work

Under this scenario, it is expected that citrus recover from the HLB condition in about a year, once the vaccine is applied. The recovery implies getting back fruit quality, no more phloem clogging and so no chlorotic leafs and full recovery of the most probable yield of 16 ton per hectare, which means to go back to original VRLP3.5.

Net income VRLP3.5V

Under this scenario Net income was assumed to be diminished because of HLB effects on citrus. Therefore, it is considered a 30% decrease from the income obtained by conventional VRLP3.5. As a result Net income is diminished because of the increase in production costs and the decrease in yield. VRLP3.5V loses 3,752 per year considering economic production costs, considering financial production costs the loss is $19,629 pesos and finally VRLP3.5 losses 4,480 pesos per year when cash flow production costs are covered (Table IV.14).

Table IV.14. Net income URP($) VRLP3.5V

Concept	Economic (1,000)	Financial (1,000)	Cash Expenditures (1,000)
Net Income	-3.75	19.67	4.48

Source: Data gathered from field work

Breakeven prices VRLP3.5, VRLP3.5M y VRLP3.5V

Breakeven price is the price needed to reimburse all costs as stated earlier. Breakeven prices consider yields stated by the citrus growers in VRLP3.5. Adjustments decreasing 40% of yields were done to assume the two alternative scenarios under a level of yields optimistic, pessimistic and the most likely (Table IV.15).

Table IV.15. Yields under different scenarios (t) VRLP3.5

Concept	VRLP3.5			VRLP3.5M			VRLP3.5V		
	Most likely	Optimistic	Pessimistic	Most likely	Optimistic	Pessimistic	Most likely	Optimistic	Pessimistic
t/month/ha	16	28	5	10.5	19.6	3.5	10.5	19.6	3.5

Source: Data gathered from field work

In order to get the breakeven prices Total costs CT were divided by t the expected yields under the stated scenarios and compared with the actual reported average price of $4,400 pesos per ton. VRLP3.5 in all cases selling price is higher than breakeven price, so it is profitable in all scenarios. However, when we compare with VRLP3.5M which considers the use of the variety resistant to HLB, during the considered year the selling price is higher than the breakeven price just when optimistic yields are obtained, otherwise the orchard is not profitable. VRLP3.5V is profitable under the same scenario. The tree URPs cover the breakeven price with the selling price just when financial costs of production are considered and expected yields are either the most likely or optimistic (Table IV.16)

Table IV.16. Breakeven Prices under different scenarios (t) VRLP3.5

Concept	VRLP3.5			VRLP3.5M			VRLP3.5V		
	Most likely	Optimistic	Pessimistic	Most likely	Optimistic	Pessimistic	Most likely	Optimistic	Pessimistic
t/month/ha	16	28	5	10.5	19.6	3.5	10.5	19.6	3.5
Economic Costs	3,789.9	2,030.3	11,369.8	5,589.4	2,994.5	16,679.0	6,452.5	3,456.7	19,357.6
Financial Costs	2,227.9	1,193.5	6,683.6	4,019.7	2,153.4	12,059.2	4,221.0	2,261.3	12,663.1
Cash flow costs	3,241.1	1,736.3	9,723.4	5,714.2	3,061.2	17,142.7	5,668.5	3,036.7	17,005.6

Source: Data gathered from field work

Prices required to get marketing objectives VRLP3.5, VRLP3.5M y VRLP3.5V

The 2012 actual reported average price of $4,400 pesos per ton was considered for calculating the prices to reach marketing objectives for all the URPs. (Table 17). All the URPs with the actual Price just can get the marketing objective of Covering variable and cash fixed costs, opportunity costs family withdrawals covering Labor and management, but earn "0" return to depreciation, equity, and risk.

Table IV.17. Prices required to reach marketing objectives ($ t^{-1} Persian lime production)

Required Prices to:	VRLP3.5	VRLP3.5M	VRLP3.5V
Realize target return on equity, land, machinery and buildings	62,533.65	88,315.7	85,812.79
Realize a profit (return to risk) just with the Persian lime production	56,848.77	80,287.6	78,011.63
Realize target return on equity and cover all other costs	47,193.76	48,695.6	48,516.44
Cover all cash obligations, including variable and cash fixed costs, principal on term debt, and personal withdrawals	37,441.00	38,942.6	38,763.68
Cover variable and fixed costs, op./fam. Labor and mngmt., and earn "0" return to depreciation, equity, and risk	16,641.00	18,142.0	17,963.68

Cover variable and cash fixed costs, op./fam. Labor and mngmt., and earn "0" return to depreciation, equity, and risk	2,962.93	4,464.5	4,285.60
Cover variable expenses only (don't produce if less than)	1,656.93	3,158.59	2,979.60

Source: Data gathered from fieldwork

IV.5. Conclusions

The four URP built in the municipality of Martinez de la Torre, Veracruz are profitable under the economic, financial and cash expenditures production costs 2012, freed of HLB and using conventional varieties of Persian lime trees.

VRLP3.5 is the most frequently found representative production unit (URP) in the region. It earns positive net income but just covers breakeven price when considering paying just financial costs and cash expenditures. The reported actual price does not cover breakeven price when a pessimistic yield scenario is considered, therefore, the URP VRLP3.5 survival is uncertain in the long run.

When introducing an improved variety HLB resistant and a treatment with a vaccine in the whole orchard the created scenarios apply just for 2012 economic scenario and the following year once the treatment was applied. Yields were modified accordingly to conditions reported in key lime cultivated in the Mexican state of Colima. Therefore it is assumed that citrus yield may decrease down to 40%. Under these conditions, it is also assumed a Net income decrease down to 30%.

For VRLP3.5M is established a scenario where HLB is affecting the orchard but the producer decides to plant HLB resistant varieties. In order to keep in business, the orchard is just starting just with the 30% of the cultivated land. Production costs increased because of producer had to pay chopping down the old trees, planting of the HLB resistant variety and all the personnel on charge of taking care of this sector of the orchard. The producer had also to consider the lost income not coming from the new plantation which will be productive in more than a year. Under these conditions, the URP just covers breakeven price when the financial production costs are taken into account. Once yield and profitability are recovered from the new sector in the orchard, it is recommended to replant a similar surface (30%) with the HLB resistant variety. This will allow the URP making a steady recovery from the HLB infection and also will maintain in business the whole grove.

For VRLP3.5M a scenario is established where HLB is affecting the orchard but the producer decides to apply a vaccine in every tree. The investment increases costs because of the acquisition of the vaccine and the labor needed to apply in every tree. The vaccine stimulates the tree's immune system so it is expected the recovering of the tree in about a year. In this scenario, it is assumed a 30% decrease in income and a 40% decrease in yield. Therefore, just under an optimistic scenario the URP would be able to make a profit and this is the reason why the producer may not adopt this strategy. A good public policy might be to encourage the vaccine treatment through a subvention program where the producers keep the productive trees but receive the vaccine just for the first year in order to make them aware of the benefits of the treatment and to realize that once they have healthier trees and recovered yields, the treatment pays by itself.

The managerial strategies for combating HLB analyzed in this paper affect the Persian lime production costs. Many of these costs are not compensated by the actual reported price found in the market. Therefore, the increase in costs could not meet the earned income and may put the URP out of business. After considering all of the above, it is recommended to clearly establishing priorities and applying treatments to keep the exports market to guarantee good economic conditions.

Martinez de la Torre municipality is the Persian lime most productive region in the Mexico. It contributes with more tan of 60% of the produced volume, therefore, the results stated in this paper withstand representative production conditions and the feasibility of the scenarios is very likely to occur under the given agronomic and phytosanitary assumptions and under the economic conditions exerted during 2012.

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CAPÍTULO V

Conclusiones Generales

Los citricultores en México han adoptado parcialmente las medidas fitosanitarias de la campaña contra el HLB, lo que tiene implicaciones negativas sobre la viabilidad económica y financiera de las unidades de producción y sociales para la región. La adopción completa de la estrategia de los tres componentes generaría mayores beneficios que los que se presentan actualmente con la aplicación parcial (insecticidas y fertilizantes)

La adopción de la estrategia de Bové es la más conveniente para los productores, dado que maximiza los beneficios netos. La adopción parcial de los componentes de la estrategia no es la mejor alternativa dado que genera menor beneficio costo. El análisis realizado confirma que, si sólo se aplican insecticidas, sin erradicar los árboles infectados, los beneficios potenciales netos no se maximizan.

El escenario B, sin control del vector y sin erradicación, es la situación que prevalecería si no se logra convencer a los productores de aplicar con todo rigor la estrategia de los tres componentes es la menos rentable. Como se puede ver las pérdidas son evidentes a partir del tercer año que se hace la detección y de 5 a 10 años el árbol tiene una producción muy baja. El escenario D es el que tiene un mayor impacto social y beneficios en la región, por lo que su implementación es la que debe ser implementada

La estrategia basada en el incremento de los niveles de fertilización compensa la disminución del rendimiento provocada por el HLB, lo que permite mantener la calidad del producto, el nivel de participación en el mercado y el nivel de ingreso. Dado que EE.UU. es el principal mercado para los productores de limón mexicano el tipo de cambio variable también tiene una gran importancia, ya que es el factor externo en el modelo que cambia el proceso de toma de decisiones, en disminuir o aumentar la cantidad de corte en el huerto y, por tanto, la cantidad ofrecida, ya sea en el mercado interno o en el mercado de Estados Unidos.

Con el uso de variedades mejoradas y vacunación, el ingreso neto es positivo solamente en términos financieros. Con el uso de vacunas se tienen ingresos netos positivos en términos financieros y de flujo de efectivo, pero no en términos económicos. Adoptar estas estrategias por parte de los productores no es atractivo por que hay que realizar una inversión que incrementa costos y que es viable únicamente en términos financieros. Para promover la adopción de cualquiera de éstas, se requiere de programas de fomento.

Las fuerzas de cambio que influyen en la producción de limón producido de México deben favorecer los ajustes de política necesarios para atender los mercados y mantener esta actividad productiva en el país.

Al observar los resultados de la presente investigación se concluye que el manejo de plagas y enfermedades, como el HLB y su vector, se requiere de una sensibilización al productor sobre la importancia de la prevención y su descidida colaboración en adoptar las estrategias de manejo recomedadas oportunamente. Bové (2006, 2014) ha hecho gran énfasis en que la mejor solución es evitar la infección, por lo que medidas preventivas como las cuarentenarias, en lugares donde la enfermedad está presente, son sumamente importantes para conservar los estatus de control y por consecuencia también conservar las fronteras abiertas a la comercialización de los productos mexicanos.

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