CALIFORNIA APPLE COMMISSION

ANNUAL REPORT 2012 – 2013

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CALIFORNIA APPLE COMMISSION

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Alexander J. Ott, Executive Director of the California Apple Commission.

STATE APPLE ACREAGE:*

Butte	-	58 acres
Colusa	-	6.5 acres
Contra Costa-		45 acres
ElDorado/Alpine-		845 acres
Fresno	-	711 acres
Humboldt-		35 acres
Inyo/Mono-		2 acres
Kern	-	1100 acres
Lake	-	6.5 acres
Mendocino-		225 acre
Merced	-	1 acre
Napa	-	10 acres
Kings	-	46 acres
Placer	-	43 acres
Riverside-		43 acres
Sacramento-		347 acres
San Benito-		316 acres
San Bernardino-		298 acres
San Diego-		286 acres
San Joaquin-		3,100 acres
Santa Cruz-		2,211 acres
Solano-		146 acres
Sonoma-		2,616 acres
Stanislaus-		1,137 acres
Sutter	-	178 acres
Tulare	-	87 acres
TOTAL	-	11,856 acres

*Total CA Apple Acreage is based on the 2010 County Crop Reports and makes no distinction between fresh, processed or farmers markets. The California Apple Commission only represents growers that produce 40,000 pounds of fresh apples.

MESSAGE FROM THE EXECUTIVE DIRECTOR

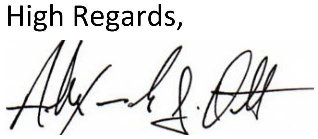
California continues to be a significant player in the early apple market. Although the golden state is the fifth largest apple producer in the U.S. it is the third largest exporter of fresh apples. Additionally, the industry is seeing plantings of early varieties of Gala and Fuji apples and removing several of the older apple varieties. In short, the industry is learning to do more with less.

The California Apple Commission is pleased to present you with its annual report for the 2012 – 2013 year. Significant accomplishments were achieved this year including: Successfully obtaining Technical Assistance for Specialty Crop (TASC) dollars to maintain California's Mexico and Taiwan Markets; obtaining Market Access Program (MAP) dollars to educate buyers about the availability of California apples; Continuing research on fire blight, Light Brown Apple Moth (LBAM) and other quarantine pest controls; managing the export programs including Mexico, Taiwan and Canada for the California apple industry; economic analysis of the removal of the starch-iodine regulation; and continuing discussions to reduce trade barriers to allow greater market access for California apples, just to name a few.

The California Apple Commission is continuing to "do those things that individual growers cannot do." This includes: Maintaining market access; protecting California apple production from harmful pests and diseases; improving quality through enhanced research; buying California first approach and providing a unified voice.

Thank you for your continued support as the Commission moves forward in representing the needs of the California apple industry.

High Regards,



Alexander J. Ott
Executive Director

THE CHAIRMAN'S CORNER

The California Apple Commission had a decent year. Although the crop was down due to a host of factors, the growers made up for it with apple crops being down in Michigan, New York and very little holdover from the Pacific Northwest. The result is an organization that continues to do more with less.

The Commission continues to assist the growers and handlers in issues that they could not do themselves. This includes market access issues for Canada, Mexico, and Taiwan. Canada continues to hint that they are looking at phytosanitary protocols for apples going north. Mexico continues to increase the cost of doing business with their inspection program and Taiwan continues to demand training for apples being shipped to their country. The end result, without the Commission, these issues would not be coordinated and addressed in a timely fashion. After all, government likes to deal with one entity, not several growers.

Additionally, growers continue to receive research on important tools needed to combat pests and diseases. Fireblight and Light Brown Apple Moth are a couple of the pests and diseases the industry deals with on a day to day basis. But, it is important to prepare for the future for those pests that are not yet here. These include Brown Marmorated Stink Bug (BMSB). This pest has taken the east by storm and is slowly making its way here to the west coast. It is important that we continue to do research and prepare should this pest enter California.

With just these mentioned issues, it is important to continue the fight and protect this small but important industry. On behalf of the California Apple Commission, I would like to thank the industry for their continued support of the Commission. Also, it is a pleasure to serve your industry as your public member and your Chairman. Here is to a successful 2014 season.

Sincerely,

Dr. Steve Blizzard
Chairman

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CALIFORNIA APPLE COMMISSION

BOARD OF DIRECTORS
2013 - 2014

DISTRICT 1	DISTRICT 2	DISTRICT 3
Producer Members	**Producer Members**	**Producer Members**
David Rider Bruce Rider & Sons Term: 7/ 2012 – 6 /2016 6/2017	**Chris Britton** BK Partners Term: 7/2010 – 6/2014	**Jeff Colombini** Lodi Farming Term: 7/2009 –
Lance Shebelut Shebelut Farms Term: 7/ 2012 – 6 /2016 6/2014	**Virginia Hemly Chhabra** Greene & Hemly Term: 7/2010 – 6/2014	**Larry Stonebarger** Chinchiolo Stemilt CA Term 7/2010 –
Tad Kozuki **Chinchiolo** Kozuki Farming, Inc. Term: 7/ 2009 – 6 /2017 6/2014	**VACANT** Term: 7/2012 – 6/2016	**Steve** Riverbend Orchards Term: 7/2010 –
Handler Member **Member**	**Handler Member**	**Handler**
Bill Denevan Denevan Apple Term: 7/ 2009 – 6 /2017 6/2017	**Dr. Bruce Hesse** Farmington Fresh Term: 7/2012 – 6/2016	**Tim Sambado** Prima Frutta Term: 7/2009 –
Alternate Member **Member**	**Alternate Member**	**Alternate**
Tim Huebert Huebert Farms Term: 7/ 2012 – 6 /2014 2012 – 6 /2014	**VACANT** Term: 7/ 2012 – 6 /2014	**VACANT** Term: 7/

PUBLIC MEMBER

Dr. Steve Blizzard
Lagomarsino Group
Term: 7/2009 – 6/2017

DISTRICT MAPS

Approved 3-7-2011

STATEMENT FOR ACTIVITIES
FISCAL YEAR ENDED JUNE 30, 2012

ASSETS

• CASH	$299,141
• ACCOUNTS RECEIVABLE	$17,300
• PREPAID EXPENSES	$3,500
• RESTRICTED CASH DUE TO PENDING LAWSUIT	$1,373,186
• PROPERTY AND EQUIPMENT NET OF ACCUMULATED DEPRECIATION OF $26,052 IN 2011 AND $21,140 IN 2010	$9,967
TOTAL ASSETS	**$1,703,094**

LIABILITIES

• ACCOUNTS PAYABLE	$31,444
• ACCRUED COMPENSATED ABSENCES	$12,992
TOTAL CURRENT LIABILITIES	**$44,436**

NET ASSETS

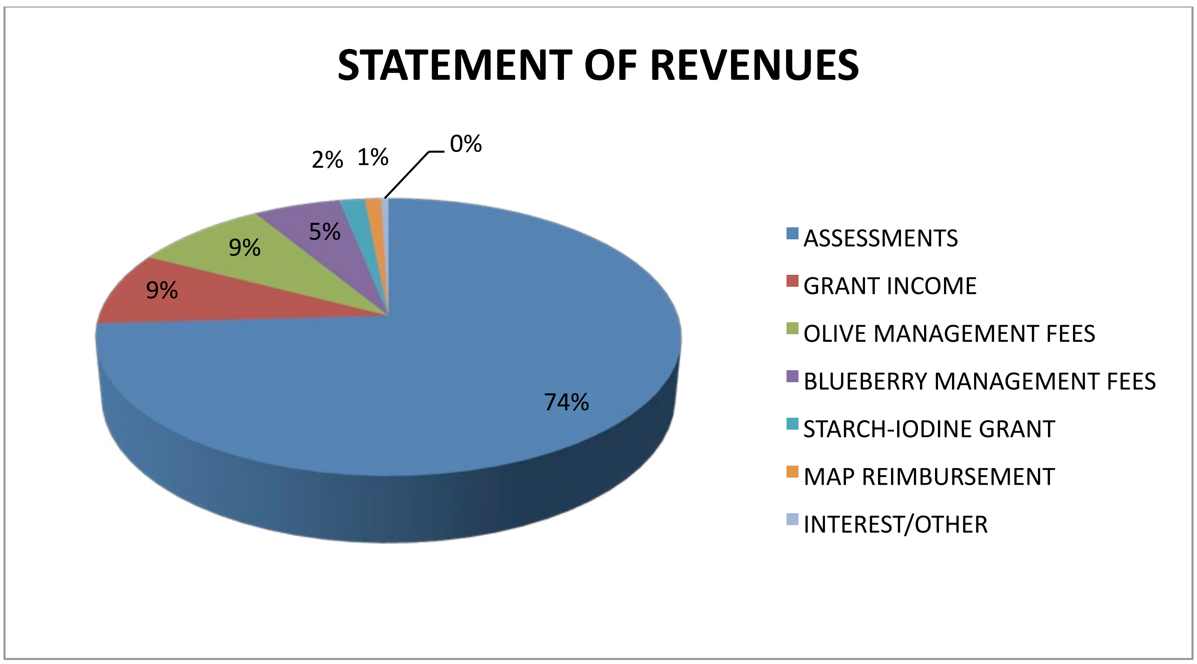
• RESTRICTED	
- ESCROW ACCOUNT	$1,373,186
• UNRESTRICTED	$285,472
NET ASSETS	**$1,658,658**

TOTAL LIABILITIES AND NET ASSETS $1,703,094

STATEMENT OF REVENUES

REVENUES

• ASSESSMENTS	$625,161*
• GRANT INCOME – TASC	$68,818
• OLIVE MANAGEMENT FEES	$70,000
• BLUEBERRY MANAGEMENT FEES	$45,000
• BLUEBERRY ASSOCIATION – FEES	$1,500
• MAP REIMBURSEMENTS	$2,874
• STARCH-IODINE GRANT	$32,064
• INTEREST	$2,390
• OTHER	$129
TOTAL REVENUES	**$847,936**



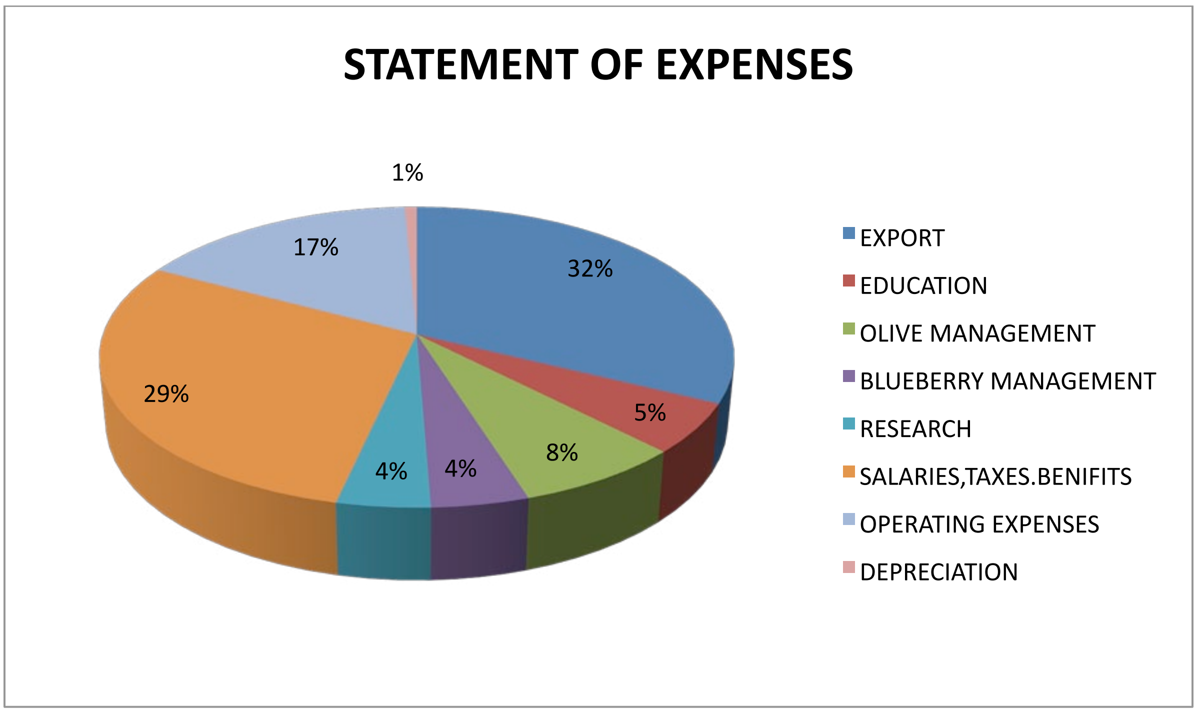
*Includes restricted revenues received pending current lawsuit. Restricted funds shall not be used in operating budget and are stored in a separate escrow account. These funds may not be released until lawsuit is finalized.

STATEMENT OF EXPENSES

EXPENSES

• EXPORT/MARKET DEVELOPMENT	$219,168
• EDUCATION	$30,917
• OLIVE MANAGEMENT	$42,117
• BLUEBERRY MANAGEMENT	$35,401
• RESEARCH	$62,724
• SALARIES, PAYROLL TAXES, BENEFITS	$207,723
• OPERATING EXPENSES	$115,794
• DEPRECIATION	$4,037

TOTAL EXPENSES **$717,881**



CHANGES IN NET ASSETS **$130,055**

NET ASSETS, BEGINNING OF YEAR **$1,528,603**

NET ASSETS, END OF YEAR **$1,658,658**

CALIFORNIA APPLE RESEARCH PROJECTS

CALIFORNIA APPLE COMMISSION RESEARCH SUMMARY 2012-2013

In 2012-2013, the California Apple Commission focused on several research projects. Some of these projects were scheduled and continuations of prior research while other projects became available or necessary during the season.

The Research Committee for the California Apple Commission approved three research proposals during the 2012 year. A forth was conducted under the California Blueberry Commission Research Committee but included apples within the research. All research projects are included within this packet.

These projects included:

1) *Evaluation of new bactericides for control of fire blight of apples caused by Erwinia amylovora and evaluation of new postharvest fungicides for pome fruits* – Dr. Jim Adaskaveg [1]

2) *The postharvest fumigation of California blueberries to eliminate insects with potential to serve as export trade barriers* – Dr. Spencer Walse, David Obenland and Steven Tebbets[2]

3) *Systems-based strategies for postharvest insect control: Mortality and removal of light brown apple moth, codling moth, brown marmorated stink bug, and other insect pests in California apples during packing and export* – Dr. Spencer Walse

4) *The postharvest fumigation of apples with Phosphine-oxygen mixtures at cold-storage temperature to eliminate the codling moth from export channels* – Dr. Spencer Walse and Steven Tebbets

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[1] $8,000 was provided by Arysta LifeScience to complete this project
[2] Funding for this research project was provided by the California Blueberry Commission. Though not specifically mentioned in the project title, it also demonstrates the effect of postharvest methyl bromide fumigation of California apples to eliminate insects with the potential to serve as export barriers.

Annual Report - 2012

Prepared for the California Apple commission

Project Title:	Evaluation of new bactericides for control of fire blight of apples caused by *Erwinia amylovora* and evaluation of new postharvest fungicides for pome fruit
Project Leader:	Dr. J. E. Adaskaveg, Department of Plant Pathology, University of California, Riverside CA 92521.
Cooperators:	L. Wade (Arysta Life Science), Dr. H. Förster, D. Felts, D. Cary, and D. Thompson

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SUMMARY

Fire blight

1. In our 2012 survey on antibiotic resistance in *Erwinia amylovora*, twenty-one isolates from orchards in several counties were obtained. In two orchards, a high level of streptomycin-resistance was present. All isolates of the pathogen belonged to the high-resistance category, and these isolates also showed reduced sensitivity to oxytetracycline. Thus, reduced sensitivity to oxytetracycline was found in two additional orchards from the ones previously identified.
2. In a field trial on the management of fire blight on Granny Smith apple with 23 treatments, Kasumin (two formulations) continued to perform very well. The 2L formulation numerically resulted in the second lowest disease incidence among the single-active ingredient treatments. Among the mixture treatments evaluated, Kasumin-Firewall, Kasumin-Fireline, Kasumin-Prophyt, and Kasumin-Manzate had the lowest incidence of disease. The biocontrol Blossom Protect (*Aureobasidium pullulans*) was also very effective in 2012, and Actinovate (*Streptomyces lydicus)* showed intermediate efficacy.
3. Kasugamycin (Kasumin) registration in the United States is pursued on pome fruit with a California registration expected in 2013.
4. In studies on the molecular mechanism of streptomycin resistance in *E. amylovora,* a new mode of resistance for moderately resistant isolates was confirmed where *strA-strB* resistance genes on transposon Tn*5393* are located on plasmid pEU30. This plasmid is also present in highly resistant isolates, but here it does not carry *strA-strB* genes. For these strains, resistance is due to a point mutation in a chromosomal gene.

Postharvest decay control

1. Postharvest experimental packingline studies using in-line drench applications were conducted to determine the efficacy of the new DMI fungicide difenoconazole and best usage rates of a new formulation of the difenoconazole-Scholar pre-mixture to ultimately provide a highly efficacious and cost-effective pre-mixture.
2. Difenoconazole showed efficacy against gray mold and was highly effective against blue mold, similar to Scholar or Penbotec. It was also highly effective against bull's eye rot. The pre-mixture at all rates tested was highly effective against the three decays and thus, there was no negative interaction between the active ingredients.
3. Fruit temperature in relation to treatment-solution temperature is an important parameter for fungicide residues on fruit. Lower fruit temperature than the treatment solution temperature reduced the amount of fludioxonil residue of Granny Smith and Fuji apple, as well as on pear.
4. Polyoxin-D that recently obtained an exempt status was similarly effective to Penbotec in reducing the incidence of gray mold, but it was not effective against blue mold. This compound is also known to be highly effective against *Alternaria* species. Thus, it has the potential to be the most effective organic treatment ever available.
5. High in vitro sensitivities of mycelial growth of *Alternaria* spp. to difenoconazole and fludioxonil indicated that these fungicides can be very effective in reducing postharvest Alternaria rot. In

agreement with the low efficacy of difenoconazole in managing postharvest gray mold, sensitivity of nine *Botrytis cinerea* isolates against this fungicide was low.

6. Resistance potential studies using the SGD method difenoconazole, fludioxonil, and pyrimethanil indicated that difenconazole has the lowest resistance potential of the three postharvest fungicides for selecting resistant isolates of the pathogen *Penicillium expansum*.

INTRODUCTION

Epidemiology and management of fire blight. Fire blight, caused by the bacterium *Erwinia amylovora,* is a very destructive disease of pome fruit trees worldwide. In addition to cankers, the pathogen overwinters in flower buds, diseased fruit, small twigs, and branches left on the ground after pruning. In the spring, blossoms are infected through natural openings in nectaries and pistils. After infecting the blossoms, the bacteria grow into the peduncles and spurs. During warm and humid weather, ooze droplets consisting of new inoculum, are exuded from the peduncles. Young fruitlets often become infected, and they also turn black, dry, shrivel, but usually remain attached to the tree. The disease spreads rapidly. After invading blossoms, the bacterial pathogen can invade adjacent leaves through stomata, trichomes, hydathodes, and through wounds caused by hail or wind whipping. Succulent twigs, suckers, sprouts, and shoots are the next tissues infected. Secondary infections may occur throughout the growing season. Inoculum is spread by wind, rain, insects, birds, or by man, e.g. by means of contaminated pruning tools. Primary and secondary infections may develop into the branch. At this time the infection, if walled off, produces a canker or it penetrates further into the branch and then into the trunk. From here the bacteria may move into other branches and finally the trunk. Trunk cankers will eventually girdle the tree and the whole tree will die. The disease can be very severe in some years, causing repeated infections during warm and wet weather.

Fire blight is one of the most difficult diseases to manage. The infection period is long, and moreover, very few effective chemicals are available. Integrated programs that combine sanitation and orchard management with chemical and biological controls are the best approaches. If the disease is in its early stage and only a few twigs are blighted, it often can be eliminated by pruning. Thus, aggressive and regular scheduled pruning of diseased tissue is essential for keeping inoculum levels low in an orchard.

Current chemical control programs for fire blight control are based on protective schedules, because available compounds are contact treatments and are not systemic. Control with copper compounds is only satisfactory when disease severity is low to moderate. These treatments are only used during dormant and bloom periods because phytotoxic effects commonly occur on fruit as russeting. Still, new formulations of copper are being developed with low metallic copper equivalent (MCE) that might not cause phytoxicity at low application rates. Antibiotics for blight control include streptomycin and the less effective oxytetracycline that both target sites in the protein biosynthesis pathway of the pathogen. Pathogen resistance against streptomycin is widespread in California.

New, more effective materials for fire blight control with a different mode of action from currently used bactericides is being developed to combat this destructive disease. These could be incorporated into a resistance management program rotations and mixtures. The most effective alternative treatment that we identified over the years with an efficacy equal to streptomycin is the antibiotic kasugamycin (Kasumin). This compound has also shown very good efficacy in controlling fire blight in other pome fruit growing areas of the country. Concerns have been expressed by regulatory agencies regarding the use of antibiotics in agriculture that are also used in human medicine, but kasugamycin is not used in human and animal medicine and has a different mode of action from streptomycin or oxytetracycline (no cross-resistance). Through our efforts, registration of Kasumin in California is expected in 2013.

Kasugamycin was again effectively used in our field trials in 2012. It was applied by itself and in mixtures with selected other materials, including biological treatments. This was done to identify effective mixture treatments that would reduce the potential for resistance development. A new material that we included in 2012 was AgriTitan, an oxidizing sanitizer for field use. Additionally, we continued to evaluate the biocontrols Actinovate (*Streptomyces lydicus*) and Blossom Protect (*Aureobasidium pullulans*), the natural products Citrox + ProAlexin, the fermentation product polyoxin-D (Ph-D), as well as the fungicide quinoxyfen (Quintec) that was shown to have antibacterial activity by us in the management of bacterial spot of tomato and by others for selected bacterial diseases. We also evaluated the reduced MCE copper compound Badge in a program with four consecutive sprays.

In another objective of our project we are investigating the molecular mechanism of streptomycin resistance in California isolates of *E. amylovora*. Several mechanisms have been described for isolates of the pathogen from various locations. The two major groups are: i) a point mutation in the chromosomal *rps*L gene; and ii) resistance genes *StrA* and *StrB* that are associated with a transposon (i.e., Tn*5393*) and that are most commonly located on one of several plasmids. Strains with a high level of streptomycin resistance are associated with the chromosomal gene; whereas, moderate resistance is associated with the *StrA* and *StrB* genes in California. We have determined that the majority of recent streptomycin-resistant isolates in California have the *StrA* and *StrB* genes. These are, however, located on a plasmid that previously has not been found to carry resistance genes. This novel mode of resistance was further investigated in 2012 in an attempt to better understand the biology of the pathogen and how it responds to selection pressures.

Management of postharvest decays. Apples, like other pome fruit, can be stored for some period of time using the correct storage environments. Still, postharvest decays caused by fungal organisms can cause serious crop losses. The major postharvest decays of apples include *Penicillium expansum, Botrytis cinerea, Alternaria alternata,* and *Mucor piriformis* causing blue mold, gray mold, black mold, and Mucor decay, respectively. Bull's eye rot caused by *Neofabraea* species can be a major problem in the apple growing areas of the Pacific Northwest, but can also cause losses in California.

New postharvest fungicides including Penbotec (pyrimethanil - 2005), Scholar (fludioxonil - 2005), and Judge (fenhexamid – 2007) were developed by us and others because Captan at the registered postharvest rate of 2 lb/200,000 lb is ineffective against blue mold and TBZ- (Mertect 340F) resistance is widespread in populations of *B. cinerea* and *P. expansum*. These new treatments are just recently being utilized in California and the Pacific Northwest (PNW) because many countries had to establish maximum residue limits (MRLs) to allow the import of fruit.

Although five fungicides (Captan, TBZ, Scholar, Penbotec, Judge) are now registered for postharvest use on apple, only two of them are highly effective against TBZ-resistant blue mold (Scholar, Penbotec). Thus, we are identifying and developing additional postharvest fungicides, and we continued our evaluation of the sterol biosynthesis inhibitor difenoconazole. Our laboratory selection studies indicated that Scholar and Penbotec have a similar high risk to develop resistance. For difenoconazole, the resistance potential has not been determined. Resistance to Penbotec in the field and in the packinghouse has already been reported in other pome fruit growing areas of the US (e.g., PNW). To prevent field resistance from developing in packinghouses, anti-resistance strategies that include the use of fungicide rotations and mixtures need to be followed. One goal is to ultimately provide a pre-mixture of fludioxonil and difenoconazole that is both highly efficacious and cost-effective. For this, we are optimizing usage rates, application methods, and we are evaluating different formulations of a pre-mixture for managing gray mold, blue mold, and bull's eye rot. Although this latter decay is only of sporadic importance in California (but very important in the Pacific Northwest), management strategies need to be known in the event of a disease outbreak. We also evaluated the effect of incubation temperature between fruit inoculation and treatment for selected fungicide applications to provide additional information on usage strategies. Temperatures during harvest and packing in late summer/fall can vary widely under California conditions, but are generally low under Pacific Northwest conditions.

In 2012, we also determined the sensitivity of *Alternaria* isolates from pome fruit to fludioxonil and difenoconazole. Both fungicides are effective against Alternaria rot. Baseline sensitivity data are used for establishing a reference point of toxicity of a fungicide to a selected population of a pathogen. This information is used to compare populations before and after introduction or registration and use of a fungicide so that changes or shifts in sensitivity can be documented. Previously, we developed baseline sensitivity data for fludioxonil and pyrimethanil against *Penicillium* and *Botrytis* spp. and for difenoconazole against populations of *P. expansum* and *Neofabraea perennans*.

None of the currently registered postharvest treatments with high efficacy is approved for organic production. Recently the bio-fungicide polyoxin-D that we have been developing for use on tree crops has obtained an exempt registration status. We previously evaluated this compound as a postharvest treatment for stone fruit and found it to be very effective on some crops (e.g., cherries), but we never evaluated it for pome fruit. With the exempt status, higher rates can now be used than recommended previously. Thus, we initiated our postharvest evaluations with polyoxin-D.

OBJECTIVES FOR 2012

1. Evaluate the efficacy of treatments for managing fire blight and characterize antibiotic resistance.
   A. Evaluate the antimicrobial kasugamycin (Kasumin) as compared to the antibiotics oxytetracycline or streptomycin and the efficacy of fungicidal compounds (e.g., Captan, Dithane, Syllit, Ph-D, and Quintec) in selected mixtures with antimicrobials
   B. Evaluate the efficacy of new biocontrol agents (i.e., Actinovate, Blossom Protect) and natural products (e.g., Cerebrocide)
   C. Evaluate the efficacy of sanitizing agents (Deccosan) and other treatments (titanium dioxide – AgriTitan).
   E. Characterization of streptomycin- and oxytetracycline-resistant strains using molecular approaches: characterize plasmids that harbor the resistance genes and compare to *E. amylovora* populations from other parts of the country.
2. Evaluate new postharvest fungicides for managing apple decays in storage
   A. Evaluate the efficacy of *final* formulations of difenoconazole alone and in mixtures with fludioxonil, TBZ, or pyrimethanil using low- and high-volume spray applications and in-line drench applications. Temperature effects will also be evaluated.
   B. Determination of baseline sensitivities and evaluation of the resistance potential
      - *P. expansum* resistance potential to difenoconazole - Exposure of large populations to a gradient of fungicide concentrations using the SGD method.
      - Determination of baseline sensitivities of fludioxonil & difenoconazole against *Alternaria* spp.
      - Determine if higher concentrations of the organic polyoxin-D fungicide are effective against blue mold.

MATERIALS AND METHODS

***Laboratory studies on the toxicity of bactericides against* E. amylovora.** Kasugamycin (Kasumin 2L, Arysta Life Sciences, Cary NC), streptomycin (Sigma, St. Louis, MO), and oxytetracycline (Sigma) were evaluated for their in vitro toxicity using the spiral gradient dilution method. For this, a radial bactericidal concentration gradient was established in nutrient agar media in Petri dishes by spirally plating out a stock concentration of each antimicrobial using a spiral plater (Autoplate 4000; Spiral Biotech, Inc., Norwood MA). After radially streaking out suspensions of the test bacteria (10 μl of 10^8 cfu/ml as determined by measurement of optical density at 600 nm) along the concentration gradient, plates were incubated for 2 days at 25ºC. Measurements were visually taken for two inhibitory concentrations: i) the lowest inhibitory concentration (LIC; the lowest concentration where inhibition of bacterial growth was observed, i.e., where the bacterial streak became less dense visually), and ii) the minimal concentration that inhibited growth by >95% (MIC). The actual antibiotic concentrations were obtained by entering the radial distances of inhibition (measured from the center of the plate) into the Spiral Gradient Endpoint computer program (Spiral Biotech, Inc.).

Isolation of* E. amylovora*, bacterial culturing, and verification of species identity. Fruit samples with fire blight symptoms were obtained in the spring and early summer of 2012 from orchards in selected counties. Infected plant material (flowers, fruit, stems, and pedicels) was surface-disinfested for 1 min using 400 mg/L sodium hypochlorite, rinsed with sterile water, cut into small sections, and incubated in 1 ml of sterile water for 15 to 30 min to allow bacteria to stream out of the tissue. Suspensions were streaked onto yeast extract-dextrose-$CaCO_3$ agar (YDC). Single colonies were transferred and the identity of the isolates as *E. amylovora* was verified by colony morphology and by PCR using primers specific for the ubiquitous *E. amylovora* plasmid pEA29 described by Bereswill et al. (Appl. Environ. Microbiol. 58:3522-2536). The presence of a 1-kb DNA fragment after gel electrophoresis confirmed a positive identification. A total of 21isolates of *E. amylovora* from eight orchard locations were obtained in 2012.

Field studies on fire blight using protective treatments during the growing season. In a field study on apple cv. Granny Smith in an experimental orchard at KARE, four treatments were applied at 30% bloom (3-21-12), 85% bloom (3-24-12), 95% bloom (4-3-12), and 100% bloom (4-15-12) using an airblast sprayer at 100 gal/A. There were five single-tree replications for each treatment. Trees were evaluated for incidence of fire blight and for potential phytotoxic effects of the treatments in May of 2012. Data were analyzed using analysis of variance and LSD mean separation procedures of SAS 9.1.

Characterization of streptomycin-resistant strains using molecular approaches. The location in the genome of the *strA-strB* resistance genes that previously were found to be associated with transposon Tn*5393* was characterized for representative California isolates of *E. amylovora*. Additionally, the exact location was determined on plasmid pEU30 by plasmid mapping. Plasmids were also isolated from sensitive, moderately resistant and highly resistant isolates using a commercial kit and digested with *Kpn*I. Fragments were separated on agarose gels and banding patterns were analyzed visually for the presence of pEU30. This work was done in collaboration with Dr. G. Sundin at Michigan State University.

Efficacy of postharvest treatments and application methods using single fungicides and mixtures. The efficacy of difenoconazole (formulation A8574D), Scholar 230SC, mixtures and pre-mixtures (i.e., A20171A) of these two fungicides at different rates, and of Penbotec was evaluated. Granny Smith apples were wound-inoculated with TBZ-resistant isolates of *B. cinerea* (10^5 conidia/ml), *P. expansum* (10^6 conidia/ml), or with *N. perennans* (10^6 conidia/ml), incubated for 16-17 h at 20C, and then treated. Before fungicide treatment, fruit were first sprayed with chlorine at 100 ppm and then rinsed with water. Fungicides were applied on an experimental packingline at the Kearney Agricultural Center as aqueous solutions using in-line drench applications that were followed by low-volume spray applications with fruit coating (Decco 231, a carnauba-based coating). After treatment, fruit were stored at 20 C, 95% RH for 6 to 8 days and then evaluated for the incidence of decay. Data were analyzed using analysis of variance and least significant difference mean separation procedures of SAS 9.1.

To evaluate the effect of fruit temperature on fludioxonil residues, Fuji and Granny Smith apple fruit or Bosc pear fruit were equilibrated to temperatures of 1.5, 12.5, or 20 C and then dipped for 30 sec in an aqueous solution of 180 ppm fludioxonil at 10C. Fruit were then air-dried and processed for residue analysis. Two experiments were done with a total of five residue values for each temperature.

***Evaluation of the resistance potential to difenoconazole in populations of* P. expansum.** In laboratory studies, selection plates with a continuous concentration gradient for difenoconazole were prepared using a spiral plater. Conidia of *P. expansum* (10^8/plate) of single-spored sensitive isolates were plated onto these selection plates, and plates were incubated for up to 7 days. Fungal colonies growing inside the EC_{95} concentration ranges were sub-cultured and evaluated for their fungicide sensitivity. Resistance frequencies were calculated based on the number of resistant isolates obtained per plate of the total number of spores plated out.

***In vitro fungicide sensitivity studies for* Alternaria *spp. and* Botrytis cinerea.** A total of 34 isolates of *Alternaria* sp. from decayed pome fruit were evaluated for their sensitivity to fludioxonil and difenoconazole, and nine isolates of *B. cinerea* were evaluated for their sensitivity against difenoconazole. Fungicide sensitivity was determined using the spiral gradient dilution method. A conidial suspension of the fungus was streaked along the radial fungicide gradient in the agar Petri dish and the 50% inhibitory concentrations for mycelial growth were determined as described previously.

RESULTS AND DISCUSSION

Survey of antibiotic sensitivity among* E. amylovora *strains collected in California. Isolates of *E. amylovora* were confirmed for species identity by PCR amplification of a 1-kb DNA fragment using specific primers for plasmid pEa29 that is ubiquitously found in this bacterium. A total of only 21 isolates from 8 orchard locations (1 to 5 isolates per location) were obtained and tested for their sensitivity against streptomycin, oxytetracycline, and kasugamycin. Still, this limited survey produced some interesting results.

In some orchards all isolates were found to be sensitive against the three antibiotics (Table 1). In other orchards (Sacramento and Fresno Co.), however, high levels of resistance against streptomycin were present. In 2012, a high level of streptomycin-resistance was present in two orchards. All isolates of the pathogen belonged to the high-resistance category, and minimum concentrations to completely inhibit growth of the bacterium exceeded 50 ppm. Furthermore, these resistant isolates all also had a reduced sensitivity to oxytetracycline. MICs of isolates sensitive to oxytetracycline were 0.09 - 0.38 ppm; whereas those for isolates with reduced sensitivity were 1.25 to 1.88 ppm. Thus, this is very similar to what we observed at a few orchard locations in 2007 and 2009: isolates with high resistance to streptomycin had a reduced sensitivity to oxytetracycline. In contrast, other isolates with high-streptomycin resistance that we found in our previous surveys were sensitive to oxytetracycline. High-streptomycin resistance that is due to a chromosomal mutation was the first type of streptomycin resistance described in West coast growing areas (Chio and Jones, 1995). Based on our surveys over the years, his type of resistance has been mostly replaced by moderate resistance where *strA-strB* resistance genes are located on plasmids. All isolates collected in 2012 were sensitive to kasugamycin.

Field studies on fire blight using protective treatments during the growing season. In a field trial to control natural incidence fire blight on Granny Smith apple, 23 treatments were evaluated using four applications each. Kasumin (two formulations) continued to perform very well (Fig. 1). The 2L formulation (that ultimately will be marketed) numerically resulted in the second lowest (after Firewall) disease incidence among the single-active ingredient treatments. Among the mixture treatments evaluated, Kasumin-Firewall, Kasumin-Fireline, Kasumin-Prophyt, and Kasumin-Manzate had the lowest incidence of disease. Mixture partners for kasugamycin and the registered antibiotics need continued evaluation to maximize the efficacy of treatments and as part of a resistance management program. A California registration of kasugamycin for pome fruit is expected for 2013. The biocontrol Blossom Protect (*Aureobasidium pullulans*) was also very effective in 2012, and Actinovate (*Streptomyces lydicus)* showed intermediate efficacy, similar to copper. In 2011, these biocontrols only numerically reduced the disease from that of the control. No new effective treatments were identified. The sanitizer AgriTitan and the biofungicide polyoxin-D were not effective at the rates evaluated. In summary, in our program identification of integrated fire blight programs with copper, fungicides, antibiotics, and biocontrols, as well as optimum application conditions (e.g., water pH) is successfully being pursued for the California pome fruit industries.

Characterization of streptomycin-resistant strains of* E. amylovora *using molecular approaches. High-resistance to streptomycin in California isolates was previously found to be correlated with a mutation in the ribosomal protein S12 (*rps*L) gene located on the bacterial chromosome, similar as was described for West coast isolates by Chio and Jones in 1995. We continued to investigate the molecular mechanism of moderate streptomycin resistance that is based on acquisition of *strA-strB* resistance genes. Based on our surveys over the past seven years, this type of resistance is currently much more common than the high-resistance based on a chromosomal mutation. We previously had confirmed the presence of *strA-strB* and transposon Tn*5393* in California isolates. It was found to be located on plasmid pEU30 that has been described from isolates from the western United States in 2004, but not on plasmid pEa34 or pEa29 as in isolates from Michigan. Thus, California isolates show a unique mode of resistance. PCR amplifications confirmed the association of *strA-strB* with pEa30 in all evaluated moderately resistant isolates that were collected between 2006 and 2011 from various locations in California (no moderately resistant isolates were found in 2012 due to limited sampling). Based on restriction enzyme analysis, plasmid pEU30 is also present in highly resistant isolates, but does not carry *strA-strB*. We continued to molecularly analyze this new mode of resistance, and in collaboration with G. Sundin, were able to determine the insertion site of the resistance genes in the plasmid. This information, together with our streptomycin resistance survey data, is currently being prepared for publication.

Efficacy of postharvest treatments using single-fungicides and mixtures. Experimental packingline studies were conduced to evaluate single-fungicide, mixture, and pre-mixture treatments (Figs. 2,3). Efficacy of most treatments against blue mold was lower in the second study (Fig. 3), most likely because fruit were more ripe and therefore more susceptible to decay. Scholar at 180 ppm in in-line drench applications effectively reduced blue mold and gray mold, but not bull's eye rot (Figs. 1,2). Difenoconazole was highly effective against blue mold and also bull's eye rot, but also against gray mold in these studies. Previously, this fungicide did not show good efficacy against gray mold, indicating that the physiology of the fruit and its susceptibility to decay determines the success of gray mold control using difenoconazole. Overall, difenoconazole should be regarded as a weak treatment for the management of gray mold; it is mostly effective against blue mold and bull's eye rot.

The registrant of difenoconazole and fludioxonil (Syngenta Crop Protection) is finalizing the formulation of a pre-mixture, and thus, we evaluated its effectiveness. At all rates tested, the pre-mixture treatments reduced the incidence of the three decays to low levels (Figs. 2,3). Thus, this pre-mixture broadens the spectrum of activity of the single fungicides with managing blue mold, gray mold, and bull's eye rot. Note that the rates used are based on both active ingredients combined and are less than 500 ppm. These three decays are also controlled by Penbotec. Resistance against pyrimethanil, however, has developed in some populations of the three decay fungi at some locations and thus, this fungicide has to be rotated with different modes of action. Although difenoconazole is not effective against gray mold, and generally did not provide an additive effect in blue mold control when used in mixtures with Scholar as compared to using Scholar alone, registration of a pre-mixture will be an important tool to decrease the risk of fungicide resistance to develop in populations of *Penicillium* spp. These results support our plans to support a difenoconazole registration for postharvest use on pears and apples through the IR-4 program.

In a study using Granny Smith apple, polyoxin-D (Ph-D) at all rates tested was similarly effective to Penbotec in controlling gray mold (Fig. 4). Blue mold, however, was not reduced as compared to the control. In preliminary studies, Ph-D was also effective against bull's eye rot. Because this material is currently one of the most effective treatments for managing Alternaria diseases of several crops (including almond where we helped to get this treatment registered), it likely will also be effective against postharvest Alternaria decays of pome fruit. Polyoxin-D recently received an exempt registration status and can be used for organic fruit production. Our data indicate that it has the potential to be the most effective organic compound we ever evaluated. Thus, we will continue our studies with Ph-D in the coming season.

Fruit temperature at treatment time affected the amount of fludioxonil residue of Bosc pear, as well as two apple cultivars. A fruit temperature of 7.5C resulted in lower residues (average of 0.26 ppm on Bosc pear) than temperatures of 12.5 or 20C (averages of 0.45 and 0.46 ppm on Bosc pear, respectively) when temperature of the treatment solution was 10C (Fig. 5). Residue levels were similar for Bosc pear and Granny Smith apple and lower than on Fuji apple. Thus, fruit temperature in relation to treatment-solution temperature is an important parameter for fungicide uptake and additional fruit temperature-treatment temperature combinations could be evaluated.

***Evaluation of the resistance potential to difenoconazole in populations of* P. expansum.** Isolates of *P. expansum* with reduced sensitivity against fludioxonil and pyrimethanil were readily obtained in previous studies when large numbers of conidia were plated on selection plates. Resistance frequencies ranged from $1x10^{-8}$ to 3.6×10^{-5} for fludioxonil and from $1.2x10^{-8}$ to 1.8×10^{-6} for pyrimethanil. For fludioxonil, isolates were either moderately resistant (EC_{50} 0.77 to 3.5 mg/L; sensitive isolates: <0.02 mg/L) or highly resistant (EC_{50} >40 mg/L), whereas for pyrimethanil a range of sensitivities (EC_{50} 1.8 to >75 mg/L; sensitive isolates: <0.70 mg/L) was observed. Isolates insensitive to both fungicides were recovered at very low frequency in some tests and always displayed a lower level of resistance. Most resistant isolates were stable in culture and were pathogenic in apple fruit inoculations. Using the same protocol in several experiments in last year's studies, no isolates with reduced sensitivity to difenoconazole were obtained (Fig. 6). Our data indicate that the risk of resistance development against new postharvest fungicides for pome fruit varies and may be high for some fungicides, and that resistance management is crucial.

***In vitro fungicide sensitivity studies for* Alternaria *spp. and* Botrytis cinerea.** Sensitivities of 34 *Alternaria* spp. isolates from pome fruit against fludioxonil and difenoconazole were within a narrow range (0.011 to 0.025 ppm for fludioxonil, 0.010 to 0.040 ppm for difenoconazole) and all isolates were highly sensitive to the two fungicides (Fig. 7A,B). This is an indication that Alternaria decays will be effectively managed by postharvest treatments with the two fungicides. Additional isolates of *Alternaria* spp. will be collected in the future to obtain a full baseline range. Supporting the low efficacy of difenoconazole in controlling gray mold, the range of EC_{50} values for nine isolates of *Botrytis cinerea* was high at 0.162 to 0.884 ppm (Fig. 8). Residue values less than 1 ppm are expected on fruit with maximum applications rates of 300 ppm difenoconazole similar to fludioxonil and thus, are insufficient to be highly effective against gray mold.

Registration status of postharvest fungicides evaluated. Scholar (fludioxonil), Penbotec (pyrimethanil), and Judge (fenhexamid) have US-EPA postharvest registration. Table 2 shows maximum residue limits (MRLs) for several fungicides in selected countries. Scholar has received MRLs and Codex tolerances in most countries of the world. Additionally, a food additive tolerance (FAT) has been obtained in Japan. The FAT for pyrimethanil in Japan is pending and MRLs are being established worldwide. Difenoconazole registration is going through the IR-4 program with federal registration pending in 2014 (MRLs have already been established for preharvest use as shown in Table 2). As indicated above, polyoxin-D is currently registered with exempt status in the United States but international exemption or MRLs need to be established in other countries.

Table 1. Incidence of resistance against streptomycin, oxytetetracycline, or kasugamycin in isolates of *Erwinia amylovora* collected in surveys of 8 California orchards in 2012

Orchard No.*	No. of isolates	Incidence streptomycin resistance (%)**	Incidence reduced oxytetracycline sensitivity (%)***	Incidence kasugamycin resistance (%)****
1	2	0	0	0
2	5	80**	80	0
7	3	0	0	0
3	4	100**	100	0
4	1	0	0	0
5	2	0	0	0
6	1	0	0	0
8	3	0	0	0
Total	21			

* - Note that some orchards had several blocks

** - Inhibitory concentrations were determined on nutrient agar using the SGD method. Minimum inhibitory concentrations (MIC, >95% inhibition) of isolates sensitive to streptomycin were 1.0 - 2.7 ppm; whereas those of isolates resistant to streptomycin were >50 ppm.

***- MICs of isolates sensitive to oxytetracycline were 0.09 - 0.38 ppm; whereas those for isolates with reduced sensitivity were 1.25 to 1.88 ppm.

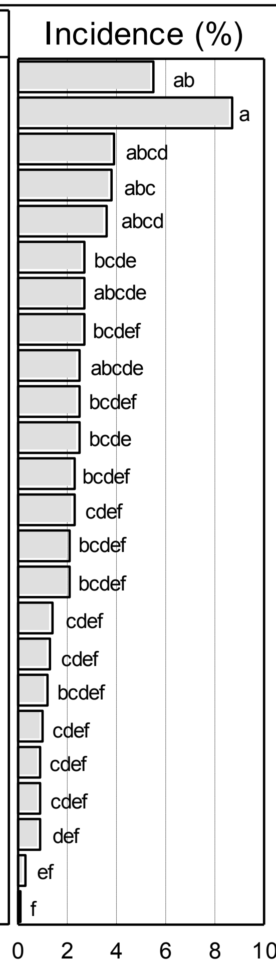
****-MICs for kasugamycin were 3.8 to 16.1 ppm.

Table 2. Maximum residue limits (MRLs) for four fungicides in the United States (US), Codex (Cod), the European Union (EU), Hong Kong (HG), Japan (Jpn), Korea (Kor), and Taiwan (Tai).

Crop	Fungicide	US *1*	Cod *2*	EU *3*	HK *4*	Jpn *5*	Kor *6*	Tai *7*
Apple	Difenoconazole	1 PPM	{0.5} PPM	{0.5} PPM	{0.5} PPM Cod	1 PPM	1 PPM	{0.5} PPM
Apple	Fludioxonil	5 PPM	5 PPM	5 PPM	5 PPM Cod	5 PPM	{1} PPM	5 PPM
Apple	Pyrimethanil	14 PPM	{7} PPM	{5} PPM	{7} PPM Cod	{5} PPM	{2} PPM	{7} PPM

Fig. 1. Efficacy of bactericides for fire blight management on Granny Smith apple in a field trial at Kearney Ag Center 2012

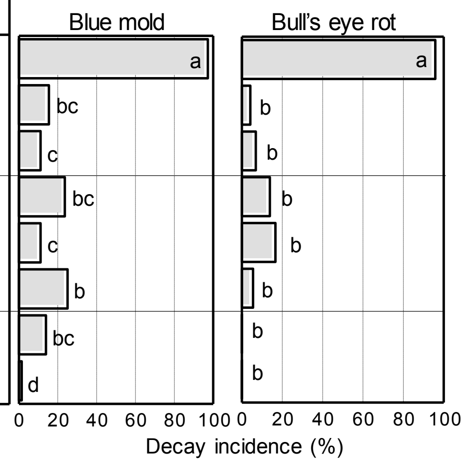
No.	Treatment*	Rate/A
1	Control	---
2	Ph-D	6.2 oz
3	Blossom Protect + Buffer + Actinovate	1.34 lbs + 9.35 lbs + 12 oz
4	Deccosan 315 foll'd by Blossom Protect + Buffer	1:50 + 1.34 lb + 9.35 lb + 8 fl oz
5	AgriTitan	1:25
6	Kasumin 2L + Captan 50WP	100 ppm + 128 oz
7	Badge X2	8 oz
8	Fireline	200 ppm
9	Kasugamycin 2L + Ph-D	100 ppm + 6.2 oz
10	Fireline + Firewall	200 ppm + 100 ppm
11	Kasugamycin 2L + Actinovate	100 ppm + 12 oz
12	Kasumin 2L + Quintec	100 ppm + 6 fl oz
13	Kasumin 2L + Syllit 65WP	100 ppm + 32 oz
14	Actinovate	12 oz
15	Deccosan 315 foll'd by Actinovate + Breakthru	1:50 + 12 oz + 8 fl oz
16	Blossom Protect + Buffer + Citrox + ProAlexin	1.34 + 9.35 lbs + 133 + 133 ml
17	Kasumin 8L	100 ppm
18	Kasumin 2L + Manzate ProStik	100 ppm + 2 lb
19	Blossom Protect + Buffer	1.34 lbs + 9.35 lbs
20	Kasumin 2L + Prophyt	100 ppm + 64 fl oz
21	Kasumin 2L	100 ppm
22	Kasumin 2L + Fireline	100 ppm + 200 ppm
23	Kasumin 2L + Firewall	100 ppm + 100 ppm
24	Firewall	100 ppm



Treatments were applied at 30% bloom (3-21-12), 85% bloom (3-24-12), 95% bloom (4-3-12), and 100% bloom (4-15-12) using an airblast sprayer at 100 gal/A. Disease was evaluated in May 2012 and the incidence was based on the number of diseased spurs of the total numberof spurs evaluated.

Fig. 2. Efficacy of bactericides for fire blight management on Granny Smith apple in a field trial at Kearney Ag Center 2012

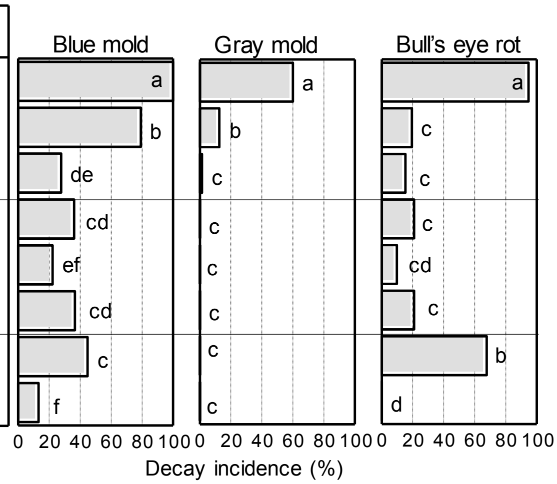
	Fungicide	Active ingredients	rate	Blue mold	Bull's eye rot
	Control (water)	---	---	a	a
	A8574D 360SC	difenoconazole	300 ppm	bc	b
	Scholar 230SC + A8574D	fludiox. + difenoc.	180 ppm + 300 ppm	c	b
New pre-mixture	A20171A 384SC	fludiox. + difenoc.	135 ppm + 225 ppm	bc	b
New pre-mixture	A20171A 384SC	fludiox. + difenoc.	157 ppm + 262 ppm	c	b
New pre-mixture	A20171A 384SC	fludiox. + difenoc.	180 ppm + 300 ppm	b	b
	Scholar 230SC	fludioxonil	180 ppm	bc	b
	Penbotec	pyrimethanil	383 ppm	d	b



Fruit were inoculated with conidia of a TBZ-resistant isolate of *Penicillium expansum* or with *Neofabraea perennans* (10^6 conidia/ml), incubated for 16-17h at 20C, and treated. In-line, aqueous, re-circulating drench applications were followed by a CDA application with carnauba fruit coating (Decco 231). Fruit were then incubated at 20 C for 6 days. A20171A is a new pre-mixture of fludioxonil and difenoconazole.

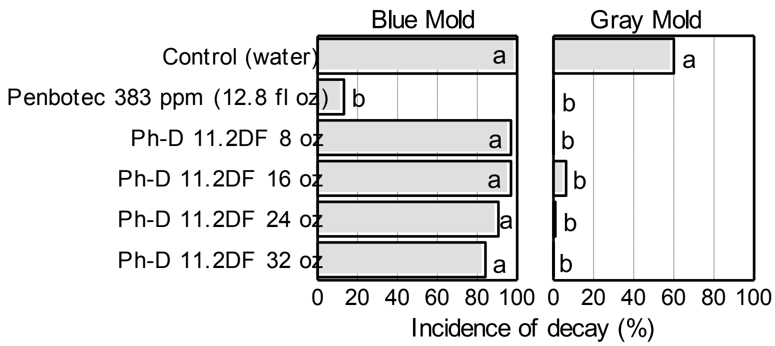
Fig. 3. Efficacy of bactericides for fire blight management on Granny Smith apple in a field trial at Kearney Ag Center 2012

	Fungicide	Active ingredients	rate	Blue mold	Gray mold	Bull's eye rot
	Control (water)	---	---	a	a	a
	A8574D 360SC	difenoconazole	300 ppm	b	b	c
	Scholar 230SC + A8574D	fludiox. + difenoc.	180 ppm + 300 ppm	de	c	c
New pre-mixture	A20171A 384SC	fludiox. + difenoc.	135 ppm + 225 ppm	cd	c	c
New pre-mixture	A20171A 384SC	fludiox. + difenoc.	157 ppm + 262 ppm	ef	c	cd
New pre-mixture	A20171A 384SC	fludiox. + difenoc.	180 ppm + 300 ppm	cd	c	c
	Scholar 230SC	fludioxonil	180 ppm	c	c	b
	Penbotec	pyrimethanil	383 ppm	f	c	d



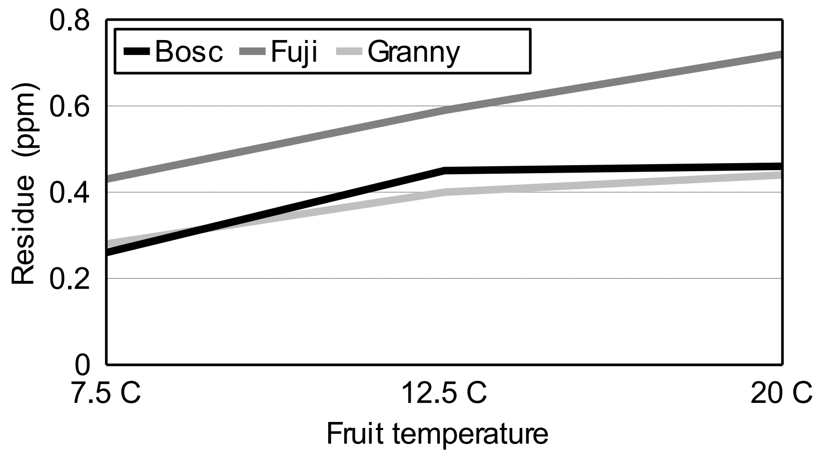
Fruit were inoculated with conidia of TBZ-resistant isolates of *Penicillium expansum* (10^6 conidia/ml) and *Botrytis cinerea* (10^5 conidia/ml), or with *Neofabraea perennans* (10^6 conidia/ml), incubated for 16-17h at 20C, and treated. In-line, aqueous, re-circulating drench applications were followed by a CDA application with carnauba fruit coating (Decco 231). Fruit were then incubated at 20 C for 6 days. A20171A is a new pre-mixture of fludioxonil and difenoconazole.

Fig. 4. Evaluation of postharvest in-line drench applications with Ph-D (polyoxin-D) for managemer blue mold and gray mold decay of Granny Smith in experimental packingline studies



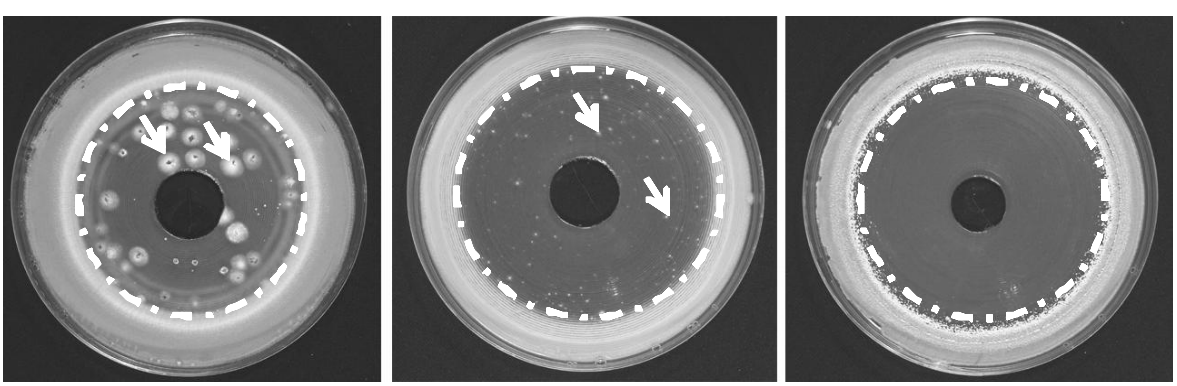
Fruit were inoculated with conidia of *Penicillium expansum* (10^6 conidia/ml) or *B. cinerea* (10^5 conidia/ml) and were incubated for 16-17 h at 20C. Treatments with aqueous fungicide solutions were done by in-line re-circulating drench applications that were followed by a CDA application with carnauba fruit coating (Decco 231). Fruit were then incubated at 20 C for 6 days.

Fig. 5. Effect of fruit temperature on fludioxonil residue after dip treatments



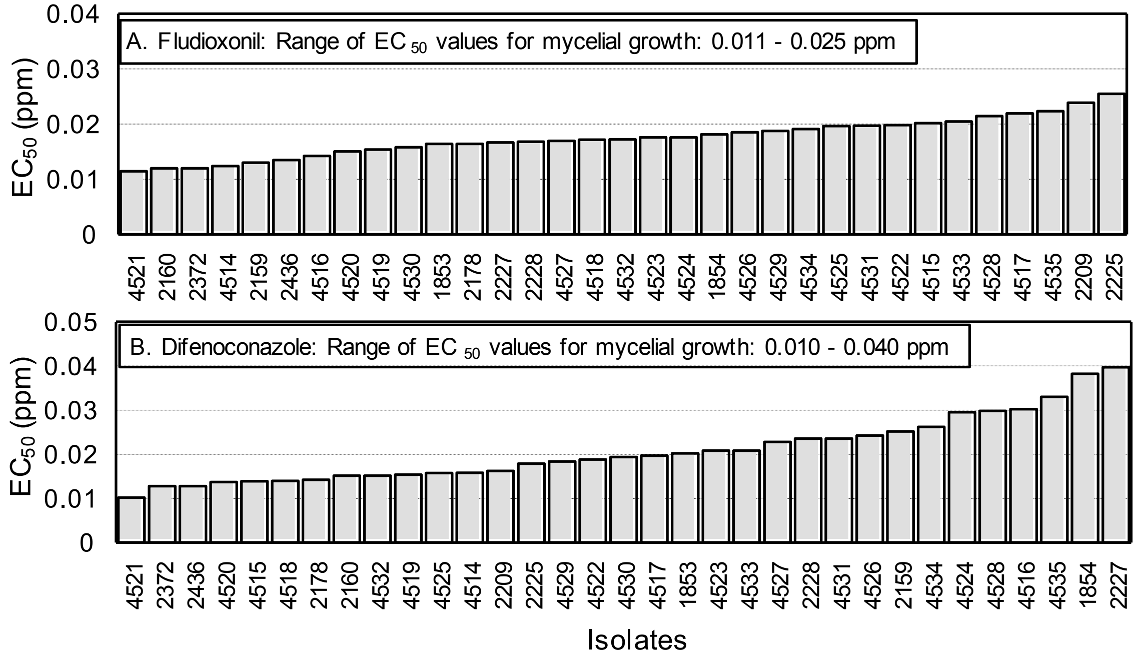
Bosc pear fruit or Fuji and Granny Smith apple fruit were equilibrated to temperatures of 1.5, 12.5, or 20 C and then dipped for 30 sec in an aqueous solution of 180 ppm fludioxonil at 10C. Fruit were then air dried and processed for residue analysis.

Fig. 6. Fungicide resistance potential assay for *Penicillium expansum* using the SGD method



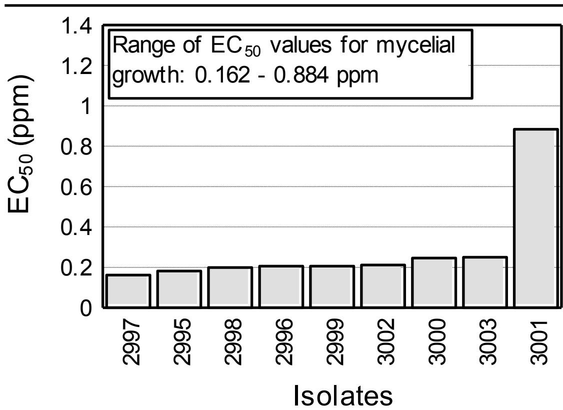
The assay was done for A. Fludioxonil on PDA; B. Pyrimethanil on AP agar; and C. Difenoconazole on PDA. High concentrations of the fungicides are near the center; whereas lower concentrations are near the perimeter of each plate. EC_{95} concentrations are shown as a dotted circle. Arrows indicate resistant isolates. Colonies are small on the pyrimethanil plates because AP media was used. No resistant isolates were detected for difenoconazole.

Fig. 7. Baseline sensitivity to fludioxonil and difenoconazole for 34 isolates of *Alternaria* spp. from pome fruit



Isolates of *Alternaria* spp. were collected from decayed fruit in packinghouses. Fungicide sensitivities for mycelial growth were determined using the spiral gradient dilution method.

Fig. 8. In vitro sensitivity to difenoconazole for 9 isolates of *Botrytis cinerea* from pome fruit



Isolates of *Botrytis* spp. were collected from decayed fruit in packinghouses. Fungicide sensitivities for mycelial growth were determined using the spiral gradient dilution method.

Residues associated with postharvest treatment of blueberries with methyl bromide to control spotted wing drosophila, *Drosophila suzukii*

by

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Abstract.

Methyl bromide (MB) chamber fumigations were evaluated for postharvest control of spotted wing drosophila, *Drosophila suzukii*, in fresh blueberries from Western USA. Blueberries were infested with SWD, infested berries containing the most MB-tolerant SWD age (72 to 120 h-old, predominately 3rd instar larvae) were buried amongst uninfested fruit in packaging consistent with commercial practice, and then the packages of blueberries were fumigated for 2- h. Treatment efficacy was diagnosed by the percentage of survivors emerging as adults from fumigated blueberries relative to that from non-fumigated controls. Over treatment temperatures of 8.3 – 17.2 (± 0.5) ºC, "CT" concentration – time cross products ranging from 80.5 – 125.6 (± 3.2) mg $L^{-1}h$ resulted in 0 survivors out of 167,670 ± 4,197 treated ($\bar{x} \pm s$) (probit 9.13, 95% L.O.C.). Fumigation efficacy > 99.9968% was observed when applied doses (mg L^{-1}) were increased incrementally as treatment temperatures (T) were lowered: 48 mg L^{-1}, T ≥ 13.9 ºC, 0 survivors out of 33,654 ± 1,025 treated; 56 mg L^{-1}, 13.9 > T ≥ 12.2 ºC, 0 survivors out of 32,179 ± 1,432 treated; 64 mg L^{-1}, 12.2 > T ≥ 10.6 ºC, 0 survivors out of 48,365 ± 2,996 treated; and 72 mg L^{-1}, 10.6 > T ≥ 8.3 ºC, 0 survivors out of 53,472 ± 2,354 treated. The rate of MB depuration (~1.5 d^{-1}) during a post-fumigation period of cold storage at 1.1 ± 0.6 °C ($\bar{x} \pm s$) as well as inorganic bromide residue levels (~5 ppm) following cold storage were evaluated and are discussed relative to each applied dosage.

Materials and Methods.

Insects.

SWD pupae were obtained from the laboratory colonies of Drs. Arytom Kopp (University of California at Davis) and Robert Van Steenwyk (University of California at Berkeley; both colonies originated from wild specimens captured in cherry orchards of coastal California USA. SWD pupae were also obtained from a laboratory colony of Dr. Jana Lee (USDA-ARS), which originated from wild specimens captured in raspberry fields of Marion County, Oregon USA. Pupae from these three sources were integrated into a single colony that was maintained in several (6-8 ct.) nylon mesh enclosures (Bug Dorm-2®, BioQuip Products, Rancho Do minguez, CA, US) housed in an 22.65-m^3 incubation unit (24-27 °C, 80% RH, 16:8 [L:D] h) at the USDA-ARS-SJVASC (Parlier, California USA). Approximately twice a year, SWD adults were captured in raspberry fields located in the Salinas Valley of California and introduced into the SJVASC colony along with new pupae from each of the original sources. Plastic vials (20-dram) containing saturated aqueous solutions of sucrose were capped with cotton wicks to serve as a food and water source for adults. Larvae were reared on standard cornmeal-(dextrose or sucrose)-agar-yeast medium layered to ($\bar{x}$ ± *s*, AVE. ± STDEV) 4.0 ± 0.6 mm on the bottom of 8.7 ± 0.1-cm diameter Petri dishes, which also served as ovipositional substrate (Figure 1). Formalin ® (2 mL), a fungistat, was added to each 4-L batch of diet. Four diet-containing Petri dishes were placed in each enclosure, replaced after 2-d ovipositional periods, and transferred to a separate communal rearing enclosure for the duration of development. When adults began to emerge from a particular dish, it was transferred back into a community of reproductively-active adults maintained at ~ 2000 individuals per enclosure.

Fruit infestation.

To simulate a naturally occurring infestation scenario, ovipositional/diet substrate was removed from an enclosure and replaced with stainless-steel trays (30 × 30 × 2 cm) that were filled with a monolayer of fresh blueberries. The stainless-steel trays containing infested blueberries were removed after 48-h ovipositional periods and maintained under rearing condition for an additional 72 h. Infested blueberries were transferred in pairs into a stainless-steel mesh ball cage (5.1-cm diameter). Mesh ball cages containing infested blueberries were randomly selected, placed inside a pull-string cloth bag (~25 per bag) and buried throughout the load of commercial fruit in confirmatory-scale fumigations. Alternatively, mesh ball cages were not fumigated and held as untreated controls to estimate the number of individuals treated during a respective fumigation. For the confirmatory fumigations, only 72 to 120-h old larvae, the most MB-tolerant age of SWD (*vide infra*), were present at the start of a 12-h pre-fumigation period of temperature equilibration (i.e., tempering).

Confirmatory export fumigations.

Commercial-scale fumigations were conducted using 241.9-L steel chambers housed in a walk-in environmental incubator with programmable temperature and humidity (USDA, 2010) set to treatment temperature of either 13.9, 12.2, 10.6, or 8.3 ± 0.5 °C ($\bar{x} \pm s$). Packaging materials were consistent with the export of California blueberries. Each chamber contained sixteen cardboard trays (25.40 x 39.37 x 8.26 cm) stacked in two eight -tray columns with tray consisting of two layers of six plastic clamshell containers (~ 170 g of fruit each). In fifteen of the trays, five clamshells in the top layer were removed the blueberries were emptied and five a stainless-steel mesh ball cages containing infested berries were loaded into the clamshells and then transferred back into the trays. In the sixteeth tray, five clamshells in the top and bottom layers were removed, loaded with infested blueberries in stainless-steel mesh ball cages, and transferred back into the trays as above. Chamber load, estimated as a percentage ($V_{commodity}/V_{chamber}$x 100) (Monro, 1969), was 55.3 ± 0.7% ($\bar{x}$ ± *s*).

Chambers loaded with infested and uninfested blueberries, bluberries infested with control specimens, source-gas cylinders, and gas-tight syringes were acclimated to fumigation temperature of, or tempered, for 12 h prior to treatment. Fruit pulp temperature was confirmed prior to fumigation by each of three probes (YSI scanning tele-thermometer) that recorded the respective pulp temperature in three uninfested cherries distributed at different locations within bins of the infested cherries undergoing treatment. Temperature probes were then removed, circulation fans internal to the chamber were turned on, and chamber lids clamp-sealed in preparation for treatment. A slight vacuum of approximately 76-127 mmHg was established in each chamber. Gas-tight super-syringes (Hamilton ® 500, 1000, or 1500 mL) were filled with a volume of MB to achieve the requisite dose as predetermined in preliminary studies to quantify load-specific sorption. A syringe was fitted to a LuerLok ® sampling valve, which was subsequently opened so that MB was steadily drawn into the chamber. The syringe was then removed and normal atmospheric pressure (NAP) was reestablished in each chamber before the valve was closed; this marked the beginning of the exposure period. Gas samples (40 mL) were taken from the chamber headspace through a LuerLok® valve using a B-D® 100 mL gas-tight syringe and quantitatively analyzed for MB with GC-FID at standard intervals corresponding to 5 (initial), 15, 30, 60, and finally 120 min. Fumigant exposures were expressed as concentration × time cross products, "CTs", and calculated by the method of Monro (1969).

After the exposure period, chamber valves were opened to atmosphere and vacuum was pulled for 4 h to aerate the chamber. Chamber lids were opened and the treated and non-treated specimens were collected, placed into respective pull-string cloth bags, and transferred into separate 0.03-m^3 nylon-mesh rearing cubicles maintained in an incubator at 27.0 ± 1.0 °C and 80 ± 2% RH ($\bar{x} \pm s$).

***Mortality evaluation*.**
Larval and egg mortality was assessed at 1-d intervals post-fumigation for 21 d; cages were removed from the cloth bags, opened, and live adult specimens were tallied and discarded. The cages were then resealed, and placed back into the cloth bags for further incubation and evaluation. An uninfested blueberry was added to the mesh ball cages approximately every third day to keep the test fruit and insects hydrated. The number of 48-96 h old (pre-fumigation age) specimens that were treated was estimated by the cumulative number of adults that emerged from untreated controls.

Rearing and incubation conditions of 27.0 ± 1.0 °C, 80 ± 2% RH, and 16:8 [L:D] h photoperiod were fixed to maintain a consistent progression of development between trials and controls; resulting mortality in control specimens was assumed to be equal to that in fumigation trials. Insects were more likely to survive and there was greater certainty in diagnosing survivorship after the treatment if incubated under conditions described above rather than if refrigerated post-fumigation at 2-5 °C under simulated commercial transport conditions, which confound the effect of a fumigation event on mortality. To be detailed in a forthcoming publication on the effect of refrigeration on SWD, we generally observed increases in the mortality of all SWD life-stages, the length of the developmental periods of each life-stage, and heterogeneity in the times required to complete development within each life-stage.

Chemical Analysis and Calibration of Standards.

MB levels in headspace of fumigation chambers were measured using gas chromatography; retention time (t_r = 3.2 min) was used for chemical verification of MB and the integral of peak area, referenced relative to liner least-squares analysis of a concentration – detector response curve, was used to determine concentration. Detector response and retention indices were determined each day in calibration studies by diluting known volumes of gaseous into volumetric gas vessels. Fumigation analyses utilized a Hewlett Packard 6890 and splitless injection (150 °C) using a gas sampling port (110 °C) with a 1 mL-sample loop, a 2 mm id x 2 m Teflon® column packed with 10% OV-101 on Gas-Chrom Q® (100/120 mesh) held at 100 °C for 10 min, and 15 $mlmin^{-1}$ He carrier flow. The FID detector was at 275 °C with respective flows of 20 $mLmin^{-1}$ H_2, 250 $mLmin^{-1}$ air, and 5.0 $mLmin^{-1}$ N_2 make-up.

Gas chromatography was also used to analyze "organic" MB residues; methods of chemical verification (t_r = 4.67 min) and quantification were as described above. For calibration studies, volumetric gas-blending jars were filled with buffer solution and non-fumigated blueberries. Measured volumes of gaseous MB were then injected through the septa covering the sampling port and then the samples were processed as described below. The Henry's law liquid-to-gas distribution coefficient of MB in the glass blending-vessels was determined to be 0.25 ± 0.6 (unitless) and was constant over a the range of 1-100,000 ppb MB. Aliquots of jar headspace were withdrawn with a 500-mL gas sampling syringe and analyzed using a Hewlett Packard 6890 gas chromatograph. Pulsed-splitless injections (250μL) were at port temperature of 125 °C and introduced via a 100μL-sample loop (100 °C) into a GasPro analytical column (L = 30 m, ID = 0.32mm), Agilent Technologies, #113-4332) with an initial pressure pulse of 30 psi for 1.9 min that was reduced to 4.0 $mLmin^{-1}$ (59 $cmsec^{-1}$) He carrier flow. Initial oven temperature of 90°C was maintained for 10 min and ramped at 40 $°Cmin^{-1}$ to a final temperature of 200 °C and held for an additional 3 min. Detection was with a μECD at 275 °C with 60mL min^{-1} N_2 make-up flow.

Inorganic bromide residues were quantified with a Tracor Spectrace (Model 431) energy dispersive X-ray fluorescence system using a modified method of Winchester (1978). X-ray tube voltage was 30 kV and the anode current was 0.21 mA. The total counts recorded in the bromine emission spectrum, referenced relative to liner least-squares analysis of a concentration – detector response curve, was used to determine concentration each day in calibration studies. Bromine-fortified samples were prepared for calibration purposes by introducing serial dilutions of ethanolic 3-bromopronionic acid into respective flasks each containing non-fumigated blueberries (100g) that were ground as described below. The fruit mixture was maintained at room temperature for 1 h and then ethanol was removed via rotavapory-concentration at 50°C. Samples were subsequently processed for analysis as described below.

Organic methyl bromide residues.

MB residues resulting from fumigation were quantified via a modified method of King et al. (1981) in a confirmatory SWD efficacy trial representing each incremental increase of applied dose (mg L^{-1}) respective to each decrease in treatment temperature (T): 48 mg L^{-1} at T = 13.9 ± 0.5 °C (trial 20); 56 mg L^{-1} at T = 12.2 ± 0.5 °C (trial 15); 64 mg L^{-1} at T = 10.6 ± 0.5 °C (trial 10), and 72 mg L^{-1} at T = 8.3 ± 0.5 °C ($\bar{x} \pm s$) (trial 5) (see Table 1). Samples for determining initial MB residue levels were gathered as described above and processed within 5-30 min of the 4 h post fumigation period (vide infra). Subsequent residue sampling occurred after the completion of aeration at daily intervals. Blueberries (~100 g) in cold-storage were randomly gathered from the boxes corresponding to each applied dose and pooled in a cloth bag to create a single sample. This process was repeated three times, and also at each daily sampling interval, to yield triplicate samples of blueberries fumigated at each respective applied dose. Each bag was emptied, 75 g of blueberries were gravimetrically measured, and then transferred to a 500-mL air-tight glass blending-vessel (Eberbach Corp., No. E8470.00) filled with 200 mL of freshly prepared and degassed 0.01M $NaHCO_3$ buffer at pH 7 (HCl-adjusted), 0.1μ NaCl, and ~15 °C. Polypropylene lids, equipped with rubber gaskets and a LuerLok ® sampling valve, were screwed into place, pressure tested for tightness-of-fit, and macerated for 1 min with a laboratory blender (Waring model no. 5BA60VL22) equipped with a General Electric 1/5 hp explosion proof motor. The motor speed was controlled with a Powerstat Variable Transformer, Type 116B, set at 80 % power. Vessels were stored at 15.0 ± 0.4 °C ($\bar{x} \pm s$) for 24 h and then an aliquot of headspace was withdrawn with a 250 μL-Pressure-Lok® glass syringe and analyzed with GC-μECD as described below; two aliquots of headspace were removed from each vessel for analysis. The concentration of MB residues (ppm, ug/g - berries) at a particular sampling interval is representative of duplicate analysis of headspace from the triplicate samples and is reported as $\bar{x} \pm s$ (n = 6).

Inorganic bromide residues.

After 7 d of cold-storage, which resulted in "organic" MB residues < 5 ppb (*vide infra*), blueberries (~150 g) were randomly gathered from the boxes respectively fumigated in confirmatory trials 20, 15, 10, and 5 and then pooled in a cloth bag to create a single sample. This process was repeated three times to yield triplicate samples of blueberries fumigated at each respective applied dose. Each bag was emptied, all the pulp was homogenized using a Hobart® tissue grinder, 100 g of blueberries were gravimetrically measured, and then packed into a cell for X-ray fluorescence analysis (Winchester, 1978). The concentration of bromide residues (ppm, ug/g - berries) at a particular sampling interval is representative of duplicate analysis of headspace from the triplicate samples and is reported as $\bar{x} \pm s$ (n = 6).

Results and Discussion.

Relative MB-tolerance of SWD life stages.

Direct and indirect methods of analysis were used to identify relatively larger mature larvae as the most MB-tolerant age of SWD in infested fresh fruit at temperature > 9°C (Walse et al., 2012 a&b). We hypothesize that this is a result of these relatively large mature larvae burrowing into the fruit to feed internally, where over a 2-h fumigation time course, fumigant concentrations are relatively lower than on the surface of the fruit. These mature larvae, which consist primarily of third instars based on methods of Kanzawa (1936 & 1939), are often observed to be completely submerged, including spiracles. On the other hand, eggs, pupae, adults, and relatively smaller immature larvae are found closer to the fruit periphery where they receive a relatively uniform exposure to fumigant concentrations in chamber headspace.

To confirm the relative proportion of SWD larval life stages present at the time of confirmatory fumigation, blueberries were removed from SWD-containing enclosures after a 48-h ovipositional period and maintained under rearing conditions (24-27 °C, 80% RH, 16:8 [L:D] h) for an additional 72 h so that only fruit were only infested with 72-120 h old larvae prior to a 12-h pre-treatment equilibration to the treatment temperature of fumigation. On five separate occasions as presented below Figure 1, the probability of a SWD life stage being present just before fumigation was determined by dissecting samples of infested berries until the life stage of ~ 1000 specimens was evaluated ($\bar{x} \pm s$; egg, 0.011 ± 0.006; 1st, 0.058±0.018; 2nd, 0.226 ± 0.036; 3rd, 0.651 ± 0.035; pupa, 0.051 ± 0.015).

Confirmatory fumigations.

A series of confirmatory fumigations were conducted in the context of verifying control of the most MB-tolerant SWD age (ca. 84 to 132-h old at fumigation) in blueberries fumigated with MB for 2 h in commercial fruit bins. Over treatment temperatures frequently used by industry, 8.3 – 17.2 (± 0.5) ºC, "CT" concentration – time cross products ranging from 84.4 – 123.4 (± 2.8) mg h L^{-1} resulted in 2 survivors out of 167,670 ± 4,197 ($\bar{x} \pm s$) treated (probit 9.13) (Table 1) (Finney, 1971) . Research identified the minimum applied dose of MB, and the corresponding "CT" exposures, required to maintain a threshold of treatment efficacy ≥ 99.9968 % across the range of temperatures. Applied doses (mg L^{-1}) were increased incrementally as treatment temperatures (T) were lowered. Fumigation at 13.9 (± 0.5) ºC with an applied dose of 48 mg L^{-1} resulted in exposures of 82.4 ± 1.4 ($\bar{x} \pm s$) and yielded 0 survivors out of 33,654 ± 1,025 treated. Fumigation at 12.2 (± 0.5) ºC with an applied dose of 56 mg L^{-1} resulted in exposures of 95.1 ± 1.9 ($\bar{x} \pm s$) and yielded 0 survivors out of 32,179 ± 1,432 treated. Fumigation at 10.6 (± 0.5) ºC with an applied dose of 64 mg L^{-1} resulted in exposures of 106.2 ± 4.2 ($\bar{x} \pm s$) and yielded 0 survivor out of 48,365 ± 2,996 treated (probit 8.88). Fumigation at 8.3 (± 0.5) ºC with an applied dose of 72 mg L^{-1} resulted in exposures of 121.2 ± 2.6 ($\bar{x} \pm s$) and yielded 0 survivors out of 53,472 ± 2,354 treated. The variation in exposures at each treatment temperature, as verified by gas-chromatographic quantification of headspace concentrations, was due to differential sorption of MB by the blueberries between replicate fumigation trials.

Results support the conclusion that a 2-h postharvest fumigation with MB can be used to control SWD and provide the technical framework of a fumigation schedule:

32 mg L^{-1} at pulp temperature of 22.2 ºC or greater
40 mg L^{-1} at pulp temperature of 17.2 ºC but less than 22.2 ºC
48 mg L^{-1} at pulp temperature of 13.9 ºC but less than 17.2 ºC
56 mg L^{-1} at pulp temperature of 12.2 ºC but less than 13.9 ºC
64 mg L^{-1} at pulp temperature of 10.6 ºC but less than 12.2 ºC
72 mg L^{-1} at pulp temperature of 8.3 ºC but less than 10.6 ºC

Note that the schedule outlined above has been accepted by Australia and Korea for the export of sweet cherries from the Western USA.

<u>Methyl bromide residues.</u>

Once the blueberries were transferred to storage at 1.1 ± 0.6 °C ($\bar{x} \pm s$), the rate of MB depuration was generally consistent and was independent of exposure dose and corresponding treatment temperature (Figure 2). The loss of MB residues from blueberries is likely a result of diffusion-controlled off-gassing and can be expressed by the differential rate equation:

$$-d[MB]/dt = k_{depuration}\ [MB] \qquad (7)$$

where k $_{depuration}$ (d^{-1}) is the observable rate constant of depuration. Experimental data supports the kinetic model; plots of "ln ($[MB]_0/[MB]_t$)" versus time ($t-t_o$) were linear, indicating that the depuration of MB displayed first-order kinetics. The rate constant of depuration, k $_{depuration}$ (d^{-1}), was the negative slope obtained from a least-squares analysis. A mean rate of degradation was 1.43 ± 0.05 d^{-1} ($\bar{x} \pm s$), which translates into an average depuration half-life of ~0.49 d under storage temperature of 1.1 ± 0.6 °C.

Inorganic bromide residues.

X-ray fluorescence spectroscopy measures total elemental bromine (Br). Levels of naturally occurring bromide and organobromo constituents were quantified in non-fumigated bluberry samples. Spectroscopic measurements of fumigated blueberry samples occurred after 7 d of cold-storage, when "organic" MB residues < 5 ppb (*vide supra*). We have attributed the levels of elemental bromine (Br) reported in fumigated blueberries samples to be predominately a result of inorganic bromide residues: 48 mg L^{-1}, 5.1 ± 1.7 ppm; 56 mg L^{-1}, 6.6 ± 1.8ppm; 64 mg L^{-1}, 6.0 ± 1.0 ppm, and 72 mg L^{-1}, 6.9 ± 1.5 ppm. Future work is planned to confirm this interpretation; bromide will be directly quantified via titration allowing the relative contribution of other Br-containing constituents toward the fluorescence measurements to be determined.

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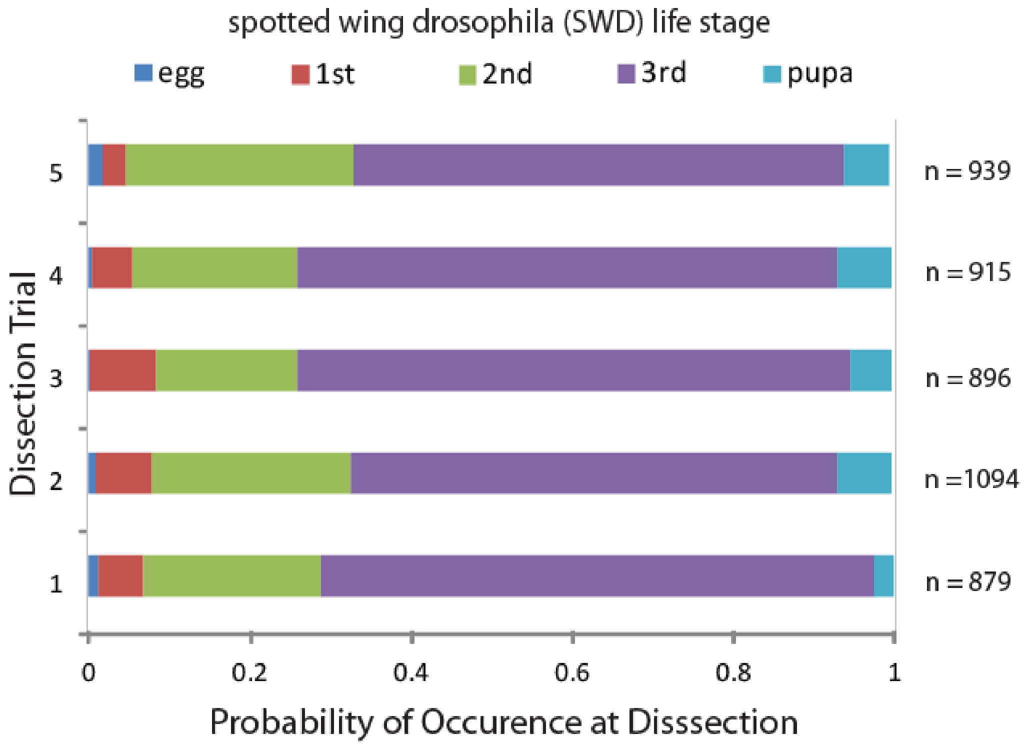

Figure 1. On five separate occasions, the probability of a SWD life stage being present just before fumigation was determined by dissecting samples of infested sweet cherry until the life stage of ~ 1000 specimens was evaluated ($\bar{x} \pm s$; egg, 0.01 ± 0.005; 1st instar, 0.051±0.011; 2nd instar, 0.223 ± 0.041; 3rd instar, 0.641 ± 0.062; pupa, 0.051 ± 0.015).

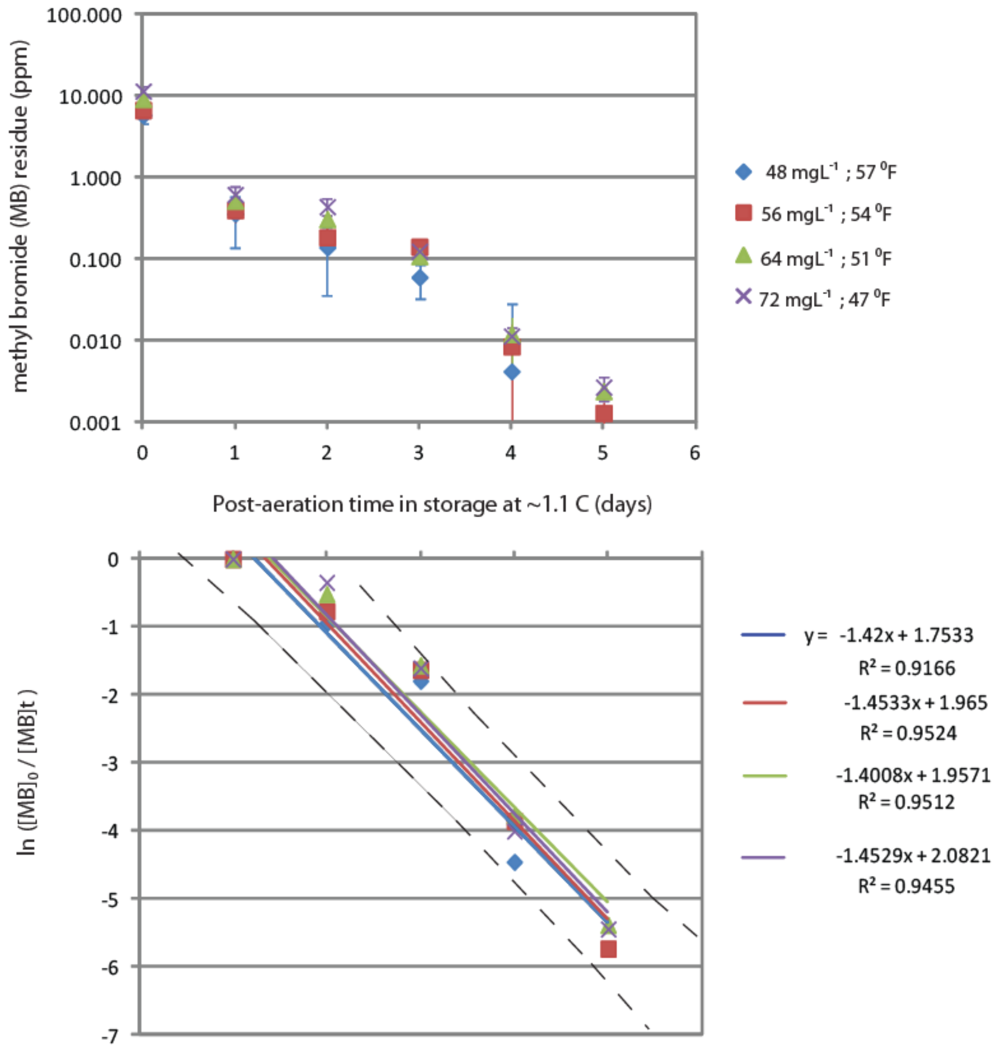

Figure 2. "Organic" MB residues (*top panel*) in fumigated blueberries decreased uniformly over the course of cold storage at 1.1 ± 0.6 °C ($\bar{x} \pm s$) with MB loss following first order kinetic approximations (*bottom panel*). The 95% confidence interval trace associated with the 64 mgL^{-1} applied dose is presented to illustrate the similarity in the rate of MB depuration from bluberries, $k_{depuration}$ (d^{-1}) (negative of slope), which occurred across all the applied dosages.

Trial #	# treated specimens			Applied (mg/L)	Temp. (±0.5 °C)	Temp. (±0.8 °F)	Load (%)	1/2 h [MB]	1 h [MB]	2 h [MB]	% Sorp.	CxT Exposure ±3.2 (mgL^{-1}h)	survivors
1	10425	±	996	72.0	8.3	47.0	55.3	69.8	63.7	49.5	31.7	125.6	0
2	10425	±	996	72.0	8.3	47.0	55.3	66.3	62.8	47.7	36.9	121.2	0
3	10874	±	1089	72.0	8.3	47.0	55.3	67.5	60.4	49.9	31.2	122.1	0
4	10874	±	1089	72.0	8.3	47.0	55.3	67.2	58.9	46.8	35.9	119.4	0
5	10874	±	1089	72.0	8.3	47.0	55.3	69.1	57.1	44.5	38.7	117.8	0
	∑ 53,472		2,354										
6	10631	±	1491	64.0	10.6	51.0	55.3	58.9	49.6	41.2	38.8	104.1	0
7	10631	±	1491	64.0	10.6	51.0	55.3	59.5	57.4	49.9	36.7	111.2	0
8	10631	±	1491	64.0	10.6	51.0	55.3	57.8	47.9	38.9	42.1	100.1	0
9	8236	±	1075	64.0	10.6	51.0	55.3	59.6	50.6	40.5	40.3	105.0	0
10	8236	±	1075	64.0	10.6	51.0	55.3	60.5	54.2	45.6	32.7	110.7	0
	∑ 48,365		1,915										
11	10723	±	1048	56.0	12.2	54.0	55.3	51.3	43.7	38.4	33.6	92.1	0
12	5364	±	488	56.0	12.2	54.0	55.3	51.9	45.6	38.4	34.7	94.0	0
13	5364	±	488	56.0	12.2	54.0	55.3	52.7	46.9	39.9	31.7	96.0	0
14	5364	±	488	56.0	12.2	54.0	55.3	55.1	46.5	36.4	37.7	95.3	0
15	5364	±	488	56.0	12.2	54.0	55.3	55.7	47.6	39.1	34.1	97.9	0
	∑ 32,179		1,432										
16	8416	±	533	48.0	13.9	57.0	55.3	45.7	40.5	36.1	35.2	82.1	0
17	8416	±	533	48.0	13.9	57.0	55.3	46.5	39.9	31.9	36.8	81.8	0
18	5274	±	401	48.0	13.9	57.0	55.3	47.1	40.5	32.6	36.3	83.0	0
19	5274	±	401	48.0	13.9	57.0	55.3	48.2	41.2	33.7	34.4	84.7	0
20	5274	±	401	48.0	13.9	57.0	55.3	45.6	39.2	31.1	36.9	80.5	0
	∑ 33,654		1,025										

Table 1. Efficacy data related to methyl bromide (MB) exposures over treatment temperatures of 8.3 – 13.9 (± 0.5) ºC. "CT" concentration – time cross products ranging from 80.5 to 125.6 (± 3.2) mg L^{-1}h cumulatively resulted in 0 survivors out of 167,670 ± 4,197 treated ($\bar{x} \pm s$)(probit 9.13).

Systems-based strategies for postharvest insect control: Mortality and removal of light brown apple moth, codling moth, brown marmorated stink bug, and other insect pests in California apples during packing and export

by

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Abstract.

Brown marmorated stink bug (BMSB), *Halyomorpha halys*, is an insect of concern to certain countries that import California apples. Efficacy requirements for standalone fumigations were lessened by developing systems-based approaches to demonstrate the removal and/or mortality of BMSB as apples are harvested, cleaned, packed, and shipped. Commercial protocols for cleaning and packing California apples were used to demonstrate that post-embryonic life stages of BMSB (1^{st}-5^{th} instar & adult) are removed from fruit that is dunked, soaked, flooded, or rolled. In addition, a toxicological response of BMSB to forced-air used in a commercial wax dryer at 128 ± 10°F was generated and regression models predict Probit 9 level mortality (99.9968%) after ≥ 3.3 min of exposure. The cumulative effect of consecutive postharvest cleaning and packing events is discussed in the context of evaluating "systemic" joint probabilities of BMSB removal and mortality prior to the entrance of fruit into export marketing channels. Several series of postharvest events typically employed by California industry are highlighted and yield removal/mortality efficacies > 99.9968%, a statistical benchmark of phytosanitary treatment efficacy. This research can be provided to regulators and trading partners to quantify the reduction in risk/threat of BMSB as apples move from production areas through packing operations toward export markets.

Materials and Methods.

Insects and Mortality. BMSB colonies originated from wild specimens captured in Kearneysville, West Virginia USA. BMSB colonies were maintained in quarantine at the BCL-3 certified Contained Research Facility on the campus of University of California at Davis. Specimens were reared in a green house on black-eyed pea plantings and feed a variety of dried figs, shelled almonds, and pumpkin seeds. The purpose of this research is to systematically demonstrate the removal of post-embryonic life stages of BMSB (1^{st}-5^{th} instar & adult) from fresh apples that have been subjected to cleaning and packing procedures standard to commercial production and distribution. Thus, BMSB eggs were not included in these studies because they are localized on leaves, which do not enter the export channels of California fresh apples. Since 2010, nearly a ton of leaf debris has been collected and incubated with no record of emerging BMSB (light brown apple moth, or oriental fruit moth).

Following treatment, treated specimens as well as untreated controls were transferred into respective cages containing a food source and incubated at 24-27 °C, 80% RH, 16:8 [L:D] h. Insects were more likely to survive and there was greater certainty in diagnosing survivorship after the treatment if incubated under conditions described above rather than if refrigerated post-fumigation at 0.5-5 °C under simulated commercial transport and storage conditions, which confound the effect of a treatment event on mortality. Mortality of treated specimens was assessed at daily intervals for 7 days following treatment. Mortality of postembryonic BMSB life stages was diagnosed visually by discoloration, while survivability was diagnosed by locomotion or by prodding-induced motion. Treated specimens were categorized as moribund if the survivability was inconclusive. Moribund specimens were placed inside a labeled plastic snap-cap cage with a food source to provide substrate and moisture prior to incubation under the conditions above until additional evaluation the following day. Control mortality was diagnosed similarly and was assumed to be equal to that in fumigation trials and was treated numerically using Abbott's method (1925) as described by Finney (1944 and 1971).

Dunking.

The removal of BMSB from the surface of fruit was examined after fruit were submerged into water, or dunked. In a series of preliminary studies it was recognized that the ability of BMSB to remain on the surface of the furit was inversely related to size (and age), therefore only the relatively small 2nd instar life stage was used in subsequent studies. BMSB (15) were collected into 15-dram clear plastic vials. Specimens were gently tapped from the vial onto the surface of a wet apple, causing them to loosely stick to the surface. Infested fruit were submerged into soak tank water (~100 ppm calcium hypochlorite and 3% sodium bicarbonate), held for either 1 s under water, removed from the water, and then evaluated for the efficiency of BMSB removal.

Soak tanks.

To simulate soak tanks used in cleaning commercial apples, at least with respect to protocols used in California, two 31-gallon plastic storage bins ("Rugged Tote", Centrex Plastics LLC, model number 314141) were modified (Figure 3). The ends of each tank were outfitted with bulkhead fittings (Grainger Inc., item # 1MKH7) with 3/4 inch male barb threads to attach clear Tygon hose (3/4 "id, 1" od, Saint-Gobaine AJC00053) secured with band clamps. Inside the tank, 90 degree "L"-fittings were attached to the bulkheads to circulate flow, and the floating fruit, as in a packing house scenario. A utility transfer pump (ZOELLER model 314-0002, portable, self priming, 115 volt AC motor, Grainger Inc. item number: 4HEX4), equipped with 3/4 inch male barb/threaded fittings as above, joined the in-flow and out-flow hoses of each tank and had a maximum flow rate of ~20 gpm (gallons per minute). The tanks were also equipped as necessary with an in-line 'point of use' water heater (American Water Heaters brand, 110V, "Tiny Titan" model) in series between the out-flow hose and the recirculation pump. Tanks were fitted with white polywall vinyl coverings, the inside of which was coated with a thin layer of Tangle-Trap (Tanglefoot Inc.) using a putty trowel. The purpose of these "sticky-lids" (Figure 3) was to trap BMSB that attempted to escape the tank.

Tanks were filled with solutions of either 100 ppm chlorine (calcium hypochlorite) and 3% sodium bicarbonate or tap water that were maintained at ~75°F. Once the solutions were added to respective tank, the circulation pumps were turned on, apples (ca. 20-25) were added to each, and groups of 15 BMSB were aspirated into a 15-dram clear plastic vial. One vial containing BMSB was submerged and shaken to remove insects and then the tank was immediately covered with the "sticky lid". Specimens were not introduced on the fruit surface as described above for dunking because in preliminary studies ~750 specimens were removed within 10 s of introduction. After 1 hour, the lids were detached and the ability of the BMSB to escape the solution was assayed by recording the number of specimens found on the lid and/or inside walls ("sides"). Between assays, BMSB were removed from the system whenever visible.

Rolling with and without Flooding.

Experiments were conducted using a laboratory-scale packing line within the quarantine facility described above. BMSB were applied to the fruit as described above for the dunking experiments. The removal of BMSB from the surface of fruit was evaluated following the passage of fruit over a 6-ft span of rollers alone and in combination with a flooder. The flooder was comprised of modified in-line soap dispenser (Decco, Inc) located at the beginning of the 6-ft span; a water supply of 10 gallon per minute was introduced into the reservoir of the dispenser that had a single exit slit to continuously yield a plane of water ~0.25 cm wide that spanned the 38-cm width of the packing line.

Drying.

A heated dryer was used to evaluate the effect of forced hot air (118-138°F) on BMSB mortality. BMSB (~25) were aspirated into 10-mL mesh brass cages that were capped with rubber stoppers. Cages were heated in the dryer for varying amounts of time (~30, 60, 90, 135, 165 s). Within three minutes of treatment, all BMSB in the cages were counted and survivability/mortality was recorded.

Results and Discussion.

Dunking.

The effect of bin drenches on BMSB removal was simulated by dunking infested fruit in soak tank water for 1 s and all but 12 out of 600 specimens were removed. Results suggest that drenching a bin will not completely remove BMSB, or at least the 2nd instar life stage, from the surface of a fruit in the bin load.

Soak tank.

BMSB were circulated in sealed soak tanks containing fruit and either ambient chlorine solution or ambient tap water with only 0.5 or 0.7%, respectively, found and presumed alive on the sides or lid of the soak tank. Only treated individuals having potentially escaped the surface tension of the bulk solution during 1 hour exposures were accounted for in post treatment evaluations, indicating that the wash solution itself was the primary reservoir for BMSB in these studies. These results support the conclusion that treated individuals sink and/or are physically destroyed by the crushing and circulating mechanics of the soak tank system. The difference in physical distribution and mortality of BMSB in ambient chlorine versus ambient tap water were tested for significance against the null hypothesis that the solution composition was unimportant. At the 95% level of confidence, the results were not significantly different using analysis of variance (Prob > F $\geq$ 0.05). Results support the conclusion that the efficacy with which soak tanks remove BMSB from the surface of apples, and the resulting mortality, result from physical entrapment by the water and drowning, rather than toxicological properties of the solution.

It is critical to note that no BMSB were found on the fruit in any of the soak tank scenarios, which indicates soaking infested fruit was effective at removing BMSB from the fruit surface as well as eliminating the return of BMSB to the fruit surface over the course of soaking (P ($E_{\Sigma \text{ soak}}$) = 0/1200 = 0.002)(Liquido & Griffin, 2010).

Rolling or Brushing with and without Flooding.

Conveying fruit over a 6-ft span of rollers alone and in combination with a flooder removed BMSB from the fruit surface with varying efficacy (Table 3). It is important to note that the vast majority of packing lines used for commercial cleaning in CA span longer than the 6ft and likely have higher removal rates of BMSB. When fruit was conveyed with rollers and a flooder was used, BMSB were completely removed from the fruit surface.

Forced-hot air dryer.

The mortality of BMSB was directly related to the duration of exposure to forced hot air in a commercial drying apparatus. Exposure-mortality regressions were generated using Probit 2007 software (Polo Plus, LeOra Software, 2002-2007); Probit 9 (P9) doses project 99.9968% mortalities. Number of insect specimens treated (n) and regression heterogeneity (H) are noted in Figure 1. Using Probit analysis (Finney, 1948) to demonstrate 99.9968% control (i.e., Probit 9) of quarantine insect pests is often required to qualify phytosanitary treatment efficacy, particularly when commodity is moved internationally (Couey and Chew, 1986; Follet and Neven, 2006). Probit 9-level treatment efficacy (99.9968% effect, probability of 0.000032) of BMSB is projected to result from ≥ 3.3 min (198s) exposure to forced-air at temperatures used in commercial dryers (118-138°F). Confirmatory exposures of 3.3 min resulted in the complete mortality of 1,000 specimens. Although the effect needs to be empirically determined, it is likely that removing one or both of the wire mesh cages would serve to decrease the exposures required for complete mortality.

Cumulative systems evaluation.

Systems approaches to quarantine security have been defined as "the integration of those pre- and post-harvest practices used in production, harvest, packing and distribution of a commodity which cumulatively meet the requirements of quarantine security" by Jang and Follett (Jang and Moffitt, 1994). The general rule for the multiplication of probabilities, expanded in the seminal work of Finney (1948) and Rosenthal (1978) on combining results (probabilities) of independent events, can be used to quantify the cumulative effect of consecutive postharvest cleaning and packing events on the "systemic" joint probabilities of BMSB removal and mortality.

For each cleaning and/or packing "event", the observed likelihood (expressed as a percentage) of finding a live BMSB after treatment, the theoretical percentage of BMSB removal and/or mortality calculated at the 95% LOC by the method of Couey and Chew (1986), and the associated probability, $P(E_x)$, is listed in Table 4. Also listed are the respective Probit values at the 95% LOC and the confidence interval associated with Probit 9 treatment efficacy as calculated by Liquido and Griffin (2010).

In the case where one event, E_1, has no effect on the probability of the other(s), the joint probability of BMSB removal/mortality associated with multiple treatment events, $P(E_1 + E_2 + En)$, can be calculated from the multiplication of the simple probability of each event (Finney, 1948):

$$P(E_1 + E_2 + En) = 1 \quad (1 \quad P(E_1))(1 \quad P(E_2))(1 \quad P(En)) \qquad \text{(eq. 1)}$$

Given equation 1, the special multiplication rule for independent events, the probability of live BMSB remaining on the surface of fruit following the joint occurrence of two or more treatment events can be calculated for numerous scenarios directly applicable to commercial apple cleaning and packing procedures used in California. For example, solution of equation 1 for consecutively soaking fruit and then conveying fruit over a 6-ft span of rollers yields a joint probability at the 95% LOC of $P(E_{\Sigma soak}, E_{roll\ \&\ spray}) = 0.00002$ (99.9980% efficacy, probit 9.11) that live BMSB are not removed from the surface of fruit. Table 5 highlights several series of events that are typically employed by California industry and which possess probabilities < 0.000015 and corresponding removal/mortality efficacies > 99.9968%, a statistical benchmark of phytosanitary treatment efficacy (Couey and Chew 1986; Follet and Neven 2006). A similar numeric-based approach to demonstrating removal/mortality efficacies > 99.9968% was recently used by the Citrus industry of California to retain export access to Australia and New Zealand (Walse 2013a).

An alternative approach to calculating the joint probability of multiple treatments, $P(E_b|E_a)$, involves multiplying the simple probability of the first event times the conditional probability of the second event, E_b, given the first, E_a:

$$P(E_b|E_a) = \frac{P(E_a \text{ and } E_b)}{P(E_a)} \qquad \text{(eq. 2)}$$

It is critical to note that even greater mortality and/or removal of BMSB would be expected if a pair or series of events was evaluated conditionally (equation 2) versus independently (equation 1), because treatments often render biological effects whereby those surviving treatment are not fully healthy, and are thus more susceptible to the subsequent treatment (Finney, 1948).

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Table 1. Dunking the infested fruit in soak tank water for 1 s removed all but 12 out of 600 specimens.

Dunking fruit			
Trial Number	Number of BMSB Used	Number Still on Fruit	Number LIVE on Fruit
1	15	0	0
2	15	0	0
3	15	0	0
4	15	0	0
5	15	1	1
6	15	0	0
7	15	0	0
8	15	0	0
9	15	2	2
10	15	0	0
11	15	0	0
12	15	1	1
13	15	0	0
14	15	0	0
15	15	0	0
16	15	0	0
17	15	0	0
18	15	0	0
19	15	2	2
20	15	0	0
21	15	0	0
22	15	0	0
23	15	0	0
24	15	1	1
25	15	0	0
26	15	1	1
27	15	1	1
28	15	0	0
29	15	0	0
30	15	0	0
31	15	0	0
32	15	1	1
33	15	0	0
34	15	1	1
35	15	0	0
36	15	0	0
37	15	2	2
38	15	0	0
39	15	0	0
40	15	0	0
TOTALS:	600	12	12
PERCENTS:	100	2.0	2.0

Table 2: Efficacy of BMSB removal from fruit subjected to recirculation soak tanks containing tap water or a solution of 100 ppm chlorine (calcium hypochlorite) at 75°F (ambient operation temperature).

Ambient Chlorine		
Trial Number	Number of BMSB Used	BMSB Escaping (lid + live sides)
1	15	0
2	15	0
3	15	0
4	15	0
5	15	0
6	15	0
7	15	0
8	15	0
9	15	0
10	15	0
11	15	0
12	15	0
13	15	0
14	15	0
15	15	0
16	15	0
17	15	0
18	15	0
19	15	0
20	15	0
21	15	0
22	15	0
23	15	0
24	15	1
25	15	0
26	15	0
27	15	0
28	15	0
29	15	0
30	15	0
31	15	0
32	15	1
33	15	0
34	15	0
35	15	1
36	15	0
37	15	0
38	15	0
39	15	0
40	15	0
TOTALS:	600	3
PERCENTS:	100	0.5

Ambient Water Only		
Trial Number	Number of BMSB Used	BMSB Escaping (lid + live sides)
1	15	0
2	15	0
3	15	0
4	15	0
5	15	0
6	15	1
7	15	0
8	15	0
9	15	0
10	15	0
11	15	0
12	15	0
13	15	0
14	15	0
15	15	0
16	15	0
17	15	0
18	15	0
19	15	0
20	15	0
21	15	0
22	15	0
23	15	0
24	15	0
25	15	1
26	15	0
27	15	0
28	15	0
29	15	0
30	15	1
31	15	0
32	15	0
33	15	0
34	15	1
35	15	0
36	15	0
37	15	0
38	15	0
39	15	0
40	15	0
TOTALS:	600	4
PERCENTS:	100	0.7

Table 3: Removal efficiency of BMSB from packing line rollers and rollers combined with flooding.

Rollers Only			
Trial Number	Number of BMSB Used	Number Still on Fruit	Number LIVE on Fruit
1	15	0	0
2	15	0	0
3	15	0	0
4	15	0	0
5	15	3	1
6	15	0	0
7	15	0	0
8	15	0	0
9	15	0	0
10	15	0	0
11	15	0	0
12	15	1	0
13	15	0	0
14	15	0	0
15	15	0	0
16	15	2	0
17	15	0	0
18	15	0	0
19	15	1	1
20	15	0	0
21	15	0	0
22	15	0	0
23	15	0	0
24	15	0	0
25	15	0	0
26	15	3	1
27	15	0	0
28	15	0	0
29	15	0	0
30	15	2	0
31	15	0	0
32	15	0	0
33	15	5	3
34	15	0	0
35	15	0	0
36	15	0	0
37	15	0	0
38	15	0	0
39	15	0	0
40	15	0	0
TOTALS:	600	17	6
PERCENTS:	100	2.8	1.0

Rollers w/ Flooder "wall of water"			
Trial Number	Number of BMSB Used	Number Still on Fruit	Number LIVE on Fruit
1	15	0	0
2	15	0	0
3	15	0	0
4	15	0	0
5	15	0	0
6	15	0	0
7	15	0	0
8	15	0	0
9	15	0	0
10	15	0	0
11	15	0	0
12	15	0	0
13	15	0	0
14	15	0	0
15	15	0	0
16	15	0	0
17	15	0	0
18	15	0	0
19	15	0	0
20	15	0	0
21	15	0	0
22	15	0	0
23	15	0	0
24	15	0	0
25	15	0	0
26	15	1	1
27	15	0	0
28	15	0	0
29	15	0	0
30	15	0	0
31	15	0	0
32	15	0	0
33	15	0	0
34	15	0	0
35	15	0	0
36	15	0	0
37	15	0	0
38	15	0	0
39	15	0	0
40	15	0	0
TOTALS:	600	1	1
PERCENTS:	100	0.1	0.1

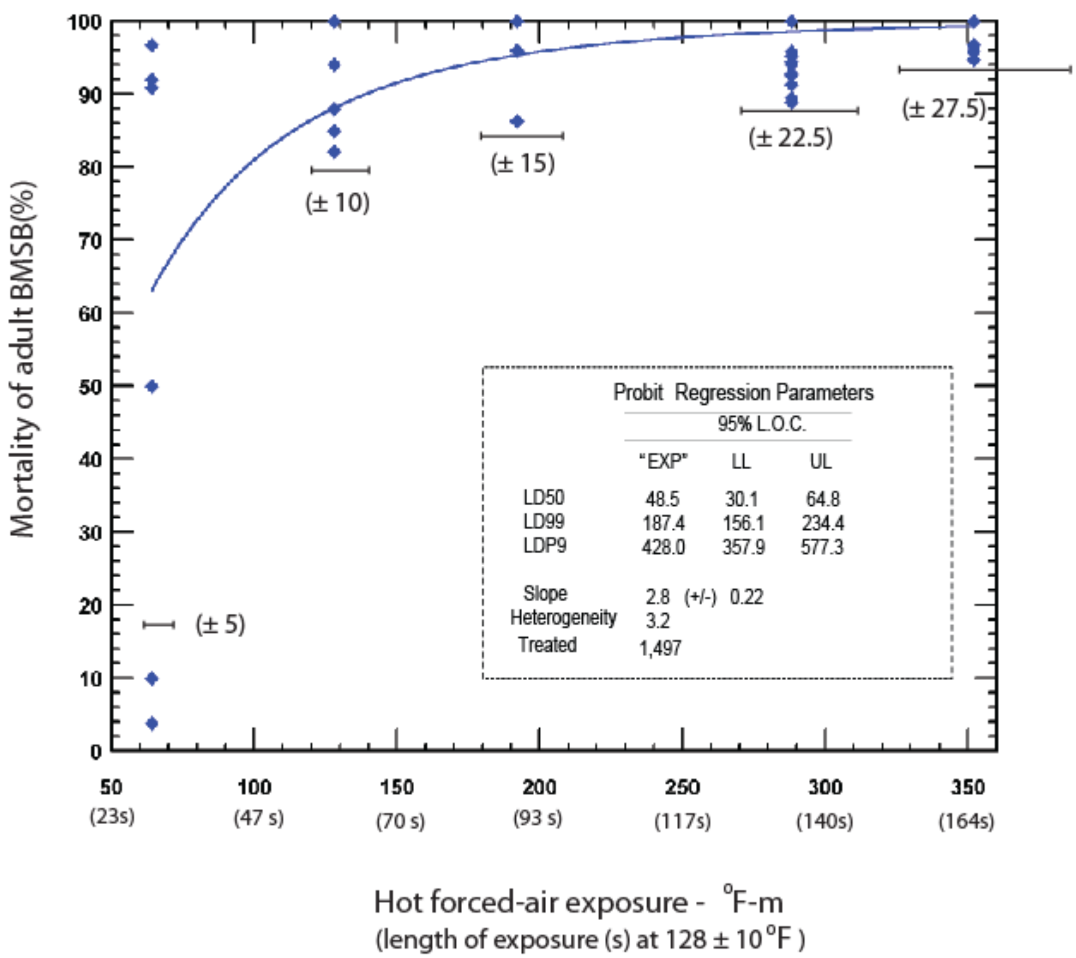
Table 4. Summary of treatment results as probabilities and probit analyses.

event *X*	observed surv. (%)	% mort. (95% LOC)	*P (Ex)* (95% LOC)	probit (95% LOC)	probit 9 (% CI)
dunking	2.0	97.06	0.02	6.89	
chlorine soak	0.5	99.02	0.005	7.34	
tap water soak	0.7	99.78	0.0067	7.25	
Σ soak	0	99.80	0.002	7.88	3.77
rollers	1.0	98.33	0.01	7.13	
roll w/ flood	0.1	99.56	0.0014	7.62	
dryer-30s	39.7	59.39	0.0466	5.09	
dryer-60s	8.5	87.53	0.1246	6.15	
dryer-90s	2.8	94.86	0.0510	6.63	
dryer-135s	1.9	97.27	0.0272	6.92	
dryer-165s	0.87	98.29	0.0171	7.12	
dryer-198s	0	99.71	0.0029	7.75	3.3

Table 5. Treatment results tabulated as joint probabilities associated with a respective series of independent events (calculated from equation 1).

joint events	% mort (95% LOC)	$P(E_1+E_2+En)$ (95% LOC)	probit (95% LOC)
Σ soak + rollers	99.980000	2.0 E-5	9.11
Σ soak + dryer-135s	99.999460	5.4 E-5	9.40
Σ soak + rollers+ dryer-135s	99.999995	5.44 E-7	10.31

Figure 1. Mortality (%) of BMSB after exposure (°F-m) to hot forced-air from a commercial dryer (118-138°F).



The postharvest fumigation of apples with Phosphine-oxygen mixtures at cold-storage temperature to eliminate the codling moth from export channels

by

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Abstract.

The Oriental fruit moth (OFM), *Grapholita molesta* (Busck), and codling moth (CM), *Cydia pomonella,* are pests of concern to countries that import apples from California. Phosphine chamber fumigations were evaluated for postharvest control of OFM and CM in apple exports from California USA. Fruit were infested with mature OFM larvae as well as mature CM larvae and fumigated with 1.6 mgL^{-1} (1000ppmv) or 3.7 mgL^{-1} (2500ppmv) phosphine for 12, 24, 36, and 48 h at 1.7 ± 0.5°C ($\bar{x} \pm s$). Complete mortality of 4,096 OFM and 4,163 CM larvae was observed following treatment having doses > 1000 ppm and treatment times > 36 h. The individual and interactive effect(s) of pressure, time, and phosphine (PH3) dose on OFM egg mortality at treatment temperature of 1.7 ± 0.5 °C ($\bar{x} \pm s$) were quantitatively delineated; a multifactorial experiment was generated and the results were analyzed using Design Expert 7.0 (Stat-Ease, Inc.). The mathematical model developed in this study predicts fumigations at 1.7 ± 0.5 °C ($\bar{x} \pm s$) with 1.6 mgL^{-1} (1000ppmv) required ~3 d treatment times for "quarantine" control of OFM (i.e., ≥ 99.9986% mortality), should the egg life stage ever occur, or be considered to occur, in the marketing channel. Ongoing research on systems-based approaches to insect pest control has not identified the occurrence of either OFM or CM eggs on annual collections of leaf litter (~750 lbs / year) grated from packing lines.

Materials and Methods.

Insects, Infestation, and Mortality. OFM and CM colonies originated from wild specimens captured in Fresno County, California USA. CM was cultured as described in Tebbets et al. (1978 & 1986) and USDA (2010) with the eggs deposited on ~3x3 cm^2 filter paper sheets over a 48-h ovipositional period. OFM was cultured as described in Yokoyama et al. (1987) and USDA (2010) with the eggs deposited on ~3x3 cm^2 wax paper sheets over a 48-h ovipositional period. Larvae were extracted for fruit infestation 14-15 days after neonates were placed on diet contents in rearing cups. Fourth (0.425-0.600mm) and fifth (0.725-0.825 mm) instar head capsule widths, were typically extracted from the respective colonies for fumigation.

To simulate naturally occurring infestation of OFM and CM larvae, apples were cored with a #4 cork borer at 6 equidistant points, equatorially around the fruit, and predominantly 5^{th} instar specimens (97%)

were placed at the center, near the pit, of each cavity. Larvae were sealed into the fruit by inserting a fruit plug, created with a #5 cork borer, until flush with the fruit skin. One day following fumigation, larval specimens were retrieved from treated and untreated controls and placed in a plastic dispo-Petri® dish lined with a filter paper for evaluation. Mortality was diagnosed visually by discoloration, while survivability of larvae was diagnosed by locomotion or by prodding-induced motion. Larvae were categorized as moribund if the survivability was inconclusive. Moribund larva were placed inside a labeled plastic snap-cap cage with fruit plugs to provide substrate and moisture prior to incubation under the conditions above until additional evaluation the following day.

Egg sheets were collected from colonies, sorted into respective groupings containing ca. 125-250 eggs, and transferred along with ~2g of wheat bran diet (to prevent egg desiccation) into 7-cm diameter Petri-dish cages modified with five 1-cm gas-portals in the lid each covered with 40-mesh stainless steel strainer cloth. Mortality of non-exposed (i.e., untreated control) and fumigant-exposed eggs was assessed following treatment after incubation for 7 d at 27.0 ± 1.0 °C and 80 ± 2% RH ($\bar{x} \pm s$). Insects were more likely to survive and there was greater certainty in diagnosing survivorship after the treatment if incubated under conditions described above rather than if refrigerated post-fumigation at 5-10 °C under simulated commercial transport and storage conditions, which confound the effect of a fumigation event on mortality. Using a microscope, exposed-egg mortality was diagnosed by the development of white coloration and survivability by vacated egg cases. Control-egg mortality was diagnosed similarly and was assumed to be equal to that in fumigation trials and was treated numerically using Abbott’s method (1925) as described by Finney (1944 and 1971).

Exploratory fumigations. To determine the treatment duration required to control OFM and CM larvae with 1.6 mgL^{-1} (1000ppmv) and 3.7 mgL^{-1} (2500ppmv) phosphine (PH3) at 1.7 ± 0.5°C ($\bar{x} \pm s$), a series of exploratory fumigations were conducted in modified Labonco® 28.32-L vacuum chambers. In a separate series of experiments, the vacuum chambers were used to quantify the individual and interactive effect(s) of treatment time, and PH3 dose on OFM egg survivability, a series of exploratory fumigations were conducted in modified Labonco® 28.32-L vacuum chambers. Chambers were housed in a walk-in environmental incubator with tunable temperature, humidity, and pressure (USDA, 2010). Test specimens, non-fumigated control specimens, source-gas cylinders, and gas-tight syringes were acclimated, or tempered, to fumigation temperature of 1.7 ± 0.5 °C ($\bar{x} \pm s$) for 12 h prior to treatment. Apples infested with OFM and CM larvae were fumigated concomitantly within a chamber for a particular fumigation trial. Cages containing the OFM eggs were fumigated in a separate series of fumigations.

A pressure of approximately 70 mmHg was established in each chamber. Gas-tight super-syringes (Hamilton ® 500, 1000, or 1500 mL) were filled with a volume of fumigant from a cylinder of 1.6 % (v/v) PH3 balanced with nitrogen (Cytec Canada, Inc., Niagara Falls, Ontario, Canada) to achieve the requisite dose as predetermined in preliminary calibration studies. A syringe was fitted to a LuerLok ® sampling valve, which was subsequently opened so that fumigant was steadily drawn into the chamber. The syringe was then removed and the pressure needed for the respective trials was established in each chamber before the valve was closed; this marked the beginning of the exposure period. Gas samples (40 mL) were taken temporally at standard intervals from the chamber headspace through a LuerLok® valve using a B-D® 100 mL gas-tight syringe and quantitatively analyzed for PH3 with GC-PFPD. For the vacuum fumigation trials, initial concentrations of fumigant in chamber headspace were based on the average headspace measurements recorded in five different fumigations at NAP having otherwise identical parameters and final 4-h concentrations were measured in samples withdrawn after the reestablishment of NAP in the chambers. Fumigant exposures were expressed as a concentration × time cross product, "CT", as calculated by the method of Monro (1969).

Following the final sampling for fumigant concentration, chamber valves were opened to atmosphere and a 1-h aeration period was initiated. Chamber lids were then opened and the treated and non-treated infested apples as well as insect cages were collected and transferred to an incubator at 27.0 ± 1.0 °C and 80 ± 2% RH ($\bar{x} \pm s$) prior to mortality evaluation.

Chemical analysis. Fumigant levels in headspace of fumigation chambers were measured using gas chromatography; retention time were used for chemical verification and the integral of peak area, referenced relative to liner least-squares analysis of a concentration – detector response curve, was used to determine concentration (Walse et al 2012a & b). Detector response and retention indices were determined each day in calibration studies by diluting known volumes of gaseous into volumetric gas vessels. PH3 analyses were with a Varian 3800 and splitless injection (140 °C) using a gas sampling port with a 10 L-sample loop, a Teflon column (L = 2 m, OD = 2 mm) packed with Porpak N (80/100 mesh) held at 130 °C for 10 min, and a PFPD detector (13 mL/min H_2, 20 mL/min air, and 10.0 mL/min N_2 make-up) at 250 °C that received only 10% of the 15 ml He/min column flow.

Multivariate Design. A multifactorial experimental design was generated and the results were analyzed using Design Expert 7.0 (Stat-Ease, Inc.). A two-factor central composite design was employed (Deming, 1993; Montgomery, 2001), which contained five levels (-α, -1, 0, 1, α) of the two factors, x_1–x_2, and six replicates of the center-point. The maximum dose value of 16 mgL^{-1} (i.e., g/m^3, oz./1000-cu. ft.) was selected based on the maximum allowable dose achieved when using cylinderized PH3 and the HDS dilution system (Fosfoquim SA, Chile). The design involved a total of 30 experiments, which were run in a randomized sequence (Table 1). The modeled response(s) (y) was egg survivability. (Table 2).

Table 1. Two factors and five factor levels used in the central composite multivariate experimental design.

Factor (original units)	*Factor levels*				
	-α	-1	0[a]	1	α
x_1: dose (ppm)	1000	2500	5000	7500	1000
x_2: duration (d)	1	2	3	4	5

[a] 0 = center point

Table 2. The experimental conditions and modeled response, OFM egg survivability.

Run	Dose (ppm)	Time (day)	Surv. (%)
1	1000	3	0
2	5000	3	50.5
3	2500	2	5.1
4	2500	4	0
5	7500	2	15.7
6	7500	2	12.9
7	5000	3	47.5
8	5000	1	87.2
9	5000	3	29.6
10	2500	2	5.2
11	5000	3	19.2
12	7500	4	9.0
13	5000	3	41.2
14	5000	1	85.6
15	7500	2	17.8
16	1000	3	0
17	10000	3	20.8
18	7500	4	7.4
19	10000	3	5.0
20	5000	1	64.6
21	1000	3	0
22	2500	2	3.7
23	7500	4	5.8
24	2500	4	0
25	5000	5	12.5
26	5000	5	15.1
27	2500	4	0
28	5000	3	66.6
29	5000	5	18.8
30	10000	3	11.0

Results and Discussion.

Fumigation of Oriental fruit moth and codling moth larvae. Mortaltiy evaluation of OFM and CM larvae following fumigation indentified that the larvae are generally more susceptible to cylinderized phosphine than eggs (Table 3) (*vide infra*). Probit regressions of the dose-mortality response will be used to quantify the relative tolerance of OFM eggs and CM eggs and LE_{P9} values required for 99.9968% (i.e., Probit 9) efficacy will be projected (Couey and Chew, 1986; Follet and Nevin, 2006).

It is interesting to note that increasing the PH3 dose from 1000ppm to 2500 ppm did not increase the efficacy of the fumigation toward either OFM or CM. This result suggests that fumigation with a minimum of 1.6 mgL^{-1} (1000ppmv) PH3 for 36 h at 1.7 ± 0.5°C ($\bar{x} \pm s$) is sufficient for control of these key apple pests. This result also suggests that there is little need to decrease the load factor in commercial apple fumigations below 50%, as sorption of PH3 by the commodity is not expected to affect efficacy/toxicology.

Table 1. Survivability of OFM and CM larvae to fumigation with 1.6 mgL^{-1} (1000ppmv) or 3.7 mgL^{-1} (2500ppmv) phosphine for 12, 24, 36, and 48 h at 1.7 ± 0.5°C ($\bar{x} \pm s$).

Trial #	cumlative # treated specimens OFM	CM	Applied (mg/L)	(ppm)	Time (hours)	Temp. (±0.5 °C)	(±0.8 °F)	survivors
1	1125	1025	1.6	1000	12	1.7	35.0	80
2	1036	965	1.6	1000	24	1.7	35.0	5
3	1259	1018	1.6	1000	36	1.7	35.0	0
4	983	1001	1.6	1000	48	1.7	35.0	0
5	1452	924	3.7	2500	12	1.7	35.0	94
6	1904	1201	3.7	2500	24	1.7	35.0	8
7	851	911	3.7	2500	36	1.7	35.0	0
8	1003	1233	3.7	2500	48	1.7	35.0	0

Multivariate analysis: OFM egg mortality. A full second-order quadratic expression was fitted to data; it contained six parameters including linear and quadratic dependencies on each factor and all possible two-factor interactions:

$$y = \beta_0 + \beta_1 x_1 + \beta_{11} x_1^2 + \beta_2 x_2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2$$

Each parameter of this full second-order model includes a coefficient: β_0, a constant or offset term; $\beta_1$and β_2, estimate the linear effects of the factors; β_{11} and β_{22} estimate the quadratic (curvature) effects of the factors; and β_{12} estimates the interaction effects between the pair of factors. Equation 1 represents the optimized model, which fitted the data with a correlation coefficient (R^2) of = 0.9465 and predicted OFM egg survivability with a correlation coefficient (R^2) of = 0.9151 (Table 4 and Figure 1).

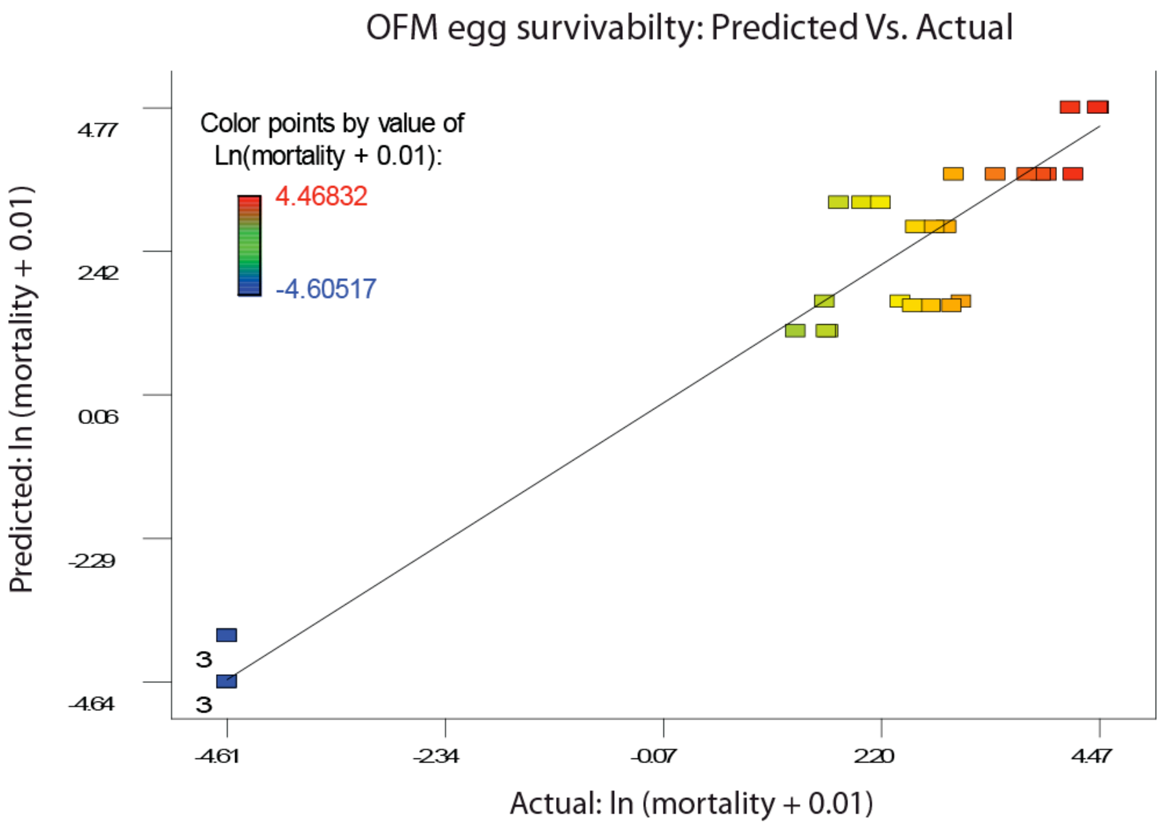
$$\ln(y + 0.01) = 3.67 + 2.2x_1 - 2.6x_1^2 - 1.15x_2 - 0.26x_2^2 + 1.35x_1x_2 \quad (1)$$

Table 4. ANOVA statistical analysis of the agreement between the model and the data regarding OFM egg survivability.

source	**sum of squares**[a]	**df**	**mean square**[b]	**F-value**[c]	**p-value**[d] **Prob > F**
model	274.9	5	54.9	84.9	< 0.0001
residual	15.5	24	0.7		
lack of fit	13.2	3	4.4	39.3	< 0.0001

a total for the sum of squares for the terms in the model
b estimate of variance, models sum of squares / model degrees of freedom
c comparison of term variance (mean square) with residual variance (res. mean square)
d probability of seeing observed F value if the null hypothesis is true (no factor effect)

Figure 1. The quadratic model, which was optimized to fit the data on OFM egg survivability, can also be used for predictive purposes to estimate the success of a fumigation event.



The coefficients (β_x) were tested for significance against the null hypothesis ($\beta_x = 0$), that the factor was unimportant in determining survivability (Table 5). At the 95% level of confidence, OFM survivability depended linearly on the dose ($\beta 1$) (positive correlation), duration ($\beta 2$) (negative correlation), interactive dose-time product (positive correlation), and quadratically on dose ($\beta 11$) (negative correlation). The following equation represents the simplified model:

$$\ln(y + 0.01) = 3.67 + 2.2x_1 - 2.6x_1^2 - 1.15x_2 + 1.35x_1x_2 \qquad (2)$$

This equation predicts OFM egg mortality of 99.9968% (Probit 9) following a 3.004-d fumigation with 1000 ppm PH3 at 1.7 ± 0.5°C ($\bar{x} \pm s$).

Table 5. ANOVA statistical tests for single parameters of the quadratic model fit to the data on navel orangeworm egg survivability.

parameter coefficient	factor effect	estimate	standard error (1df)	sum of squares [a]	F value [b]	p-Value [c] prob > F
β_0	intercept	3.67	0.33			
β_1	dose	2.20	0.16	116.5	179.91	**< 0.0001** [d]
β_2	time	-1.15	0.16	31.7	48.96	**< 0.0001** [d]
β_{12}	dose-time	1.35	0.23	21.81	33.68	**< 0.0001** [d]
β_{11}	dose - dose	-2.60	0.22	92.74	143.21	**< 0.0001** [d]
β_{22}	time - time	-0.26	0.22	0.96	1.48	0.2356

a *n* of experiments / 4 x squared factor effect
b comparison of term variance (mean square) with residual variance (res. mean square)
c probability of seeing observed F value if the null hypothesis is true (no factor effect)
d tests as significant at the 95% confidence level

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CALIFORNIA APPLE COMMISSION
FUTURE RESEARCH 2013-2014

In the beginning of 2013, the Research Committee for the California Apple Commission discussed current and future research projects. Four projects were recommended for extension to the Board of Directors for approval for the 2013-2014 season. All of the projects are a continuation of 2012-2013 season. These projects include:

1) *Evaluation of new bactericides for control of fire blight of apples caused by Erwinia amylovora and evaluation of new postharvest fungicides for pome fruits* - Dr. Jim Adaskaveg

2) *The postharvest fumigation of California blueberries to eliminate insects with potential to serve as export trade barriers* - Dr. Spencer Walse and Steven Tebbets

3) *Systems-based strategies for postharvest insect control: Mortality and removal of light brown apple moth, codling moth, brown marmorated stink bug, and other insect pests in California apples during packing and export* - Dr. Spencer Walse and Steven Tebbets

4) *The postharvest fumigation of apples with Phosphine-oxygen mixtures at cold-storage temperature to eliminate the codling moth from export channels* - Dr. Spencer Walse, Steven Tebbets, and David Obenland

<u>**2013/2014**</u>	<u>**Amount**</u>
Jim Adaskaveg- Evaluation of Bactericide…	$ 16,000[1]
Spencer Walse- The postharvest fumigation (MB)…	$ 0[2]
Spencer Walse- Systems based strategies…	$ 7,345
Spencer Walse- The postharvest fumigation…	$ 12,472
FISCAL IMPACT FOR 2013/2014:	$ 27,817

Complete research projects and completed research thus far are included within this report.

[1] Arysta LifeScience will contribute $8,000 to help fund this project

[2] Funding for this project will be provided by the California Blueberry Commission at a value of $20,417. Though not specifically mentioned, this future research will also include the effect of postharvest fumigation of California apples to eliminate insects with the potential to serve as export trade barriers.

AES/CE MAR 84

Workgroup: Apple
Department: Plant Pathology/ UCR

University of California
Division of Agricultural Sciences
PROJECT PLAN/RESEARCH GRANT PROPOSAL

Project Year: 2013 Anticipated Duration of Project: 2nd year of 3 years

Principal Investigators: J. E. Adaskaveg
Cooperating: D. Thompson, D. Cary, and H. Förster

Project Title: Evaluation of new bactericides for control of fire blight of apples caused by *Erwinia amylovora* and evaluation of new postharvest fungicides for pome fruits

Keywords: Chemical and biological control

JUSTIFICATION/ BACKGROUND

Epidemiology and management of fire blight. Fire blight, caused by the bacterium *Erwinia amylovora,* is one of the most destructive diseases of pome fruit trees including apples. The name is descriptive of the most characteristic symptom of the disease, a blackening of twigs, flowers, and foliage as though they have been damaged by fire. The disease is indigenous to North America but has since spread worldwide. In addition to cankers, the pathogen overwinters in flower buds, diseased fruit, small twigs, and branches. In the spring, blossoms are infected through natural openings in nectaries and pistils. After destroying the blossom, the bacteria spread into the peduncle, spur, and twig. During warm, humid weather, ooze droplets consisting of new inoculum are exuded from the peduncles. Inoculum is spread by wind, rain, insects, birds, or by man, e.g., by means of contaminated pruning tools. Secondary infections may occur throughout the growing season.

Current chemical control programs for fire blight control are based on protective schedules, because available compounds are contact treatments and are not systemic. Control with copper compounds is only satisfactory when disease severity is low to moderate. These treatments are only used during dormant and bloom periods because phytotoxic effects commonly occur on fruit as russeting. Still, new low metallic copper equivalent (mce) copper products can contribute to disease control and resistance management. Antibiotics for blight control include streptomycin and the less effective oxytetracycline (Mycoshield) that both target sites in the protein biosynthesis pathway of the pathogen. Others have indicated that the latter antibiotic is not persistent and degrades under UV light and rainfall in short periods of time (Christiano et al. 2009, Plant Disease 94:1213-1218). Pathogen resistance against streptomycin is widespread in California. We started to characterize streptomycin resistance in current California populations of the pathogen on a molecular base. We found that the same resistance genes are involved as described from other locations, however, these genes are located on a different plasmid that previously has not been reported to harbor streptomycin resistance anywhere else in the world. Thus, resistance in California populations of *E. amylovora* is based on a novel mechanism of the pathogen and we will continue our studies on this. In recent years, we detected isolates of *E. amylovora* with reduced sensitivity to oxytetracycline at two locations and at two additional locations in 2012 for a total of 4 locations. At one of these locations, field treatments with Mycoshield were reported to be ineffective in controlling the disease and thus, field resistance has occurred in some locations (*see* 2009 Annual Report).

New materials for fire blight control have to be developed in order to initiate resistance management practices that ensure that resistance to oxytetracycline will not spread in the pathogen population. Furthermore, the incidence of resistance against streptomycin can possibly be reduced if more rotational treatments are available, making this important management tool more effective again. Our survey data on streptomycin resistance in the pathogen population indicated a direct correlation of high incidence of resistance with high-disease occurrence (e.g., 2007, 2009, and 2011). As previously described and modeled by several researchers, incidence of disease is directly related to favorable environments, namely warming temperatures during the bloom. Rainfall and insects exacerbate disease development. Although the incidence of resistance decreased in years of low disease occurrence, our data indicate that isolates resistant to streptomycin appear to be fit and the resistant pathogen population is stable in locations that were repeatedly sampled over different seasons.

An ideal material should be effective, locally systemic, not be phytotoxic, should target multiple sites of action within the bacterial pathogen, and have a mode of action different from currently used bactericides. Materials with different modes of action could then be incorporated into a resistance management program. In our previous research, we evaluated a wide-range of materials. Kasugamycin was the material selected with the highest efficacy and registration potential. Kasugamycin is known to have high activity against bacteria, including species of *Erwinia* and *Pseudomonas*, and has some activity against *Xanthomonas* spp. and several fungal diseases. Members of the kasugamycin antibiotic class are not being used in human and animal medicine. Kasugamycin has a different mode of action from streptomycin or oxytetracycline and there is no cross-resistance known to occur. The federal registration package was submitted to EPA in January 2010 and thus, the registration in the United States is pending in April 2013 with California registration following in 2014. In previous years, we evaluated different rates of the antibiotic and application volumes, as well as its performance in rotations. We also established the *in vitro* baseline sensitivity for kasugamycin using over 400 isolates of *E. amylovora*. All isolates showed a similar sensitivity and there was no cross resistance between streptomycin and kasugamycin.

In more recent research, some broad-spectrum fungicides such as Captan, Dithane (mancozeb), and Syllit (dodine) showed efficacy in reducing the disease, and in combination with kasugamycin sometimes increased the antibiotic's activity. Additionally in 2011 and 2012, the fungicide Quintec, presumably functioning as an SAR material, showed efficacy in combination with Kasumin. Other new systemic acquired resistance or SAR materials that deserve continued evaluation include ProAlexin, a product based on citrus and palm extracts, Actigard, and PM-1. These products have been shown to activate the plant's defense system through the production of phytoalexins or certain pathogenicity-related proteins that are non-specific defense chemicals. Possibly these compounds can be used in combination with other bactericides to enhance their efficacy. Furthermore, SAR compounds may have a longer lasting effect on the plant's defense activation. New formulations of copper allow for reduced rates of metallic copper equivalent (MCE) and thus, extended usage past the bloom period may provide an effective rotational treatment without causing russeting. Combinations of Kasumin and copper products were tested in 2012 and were shown to be effective. This research needs to be continued.

In trials in 2009-2011, the natural product Cerebrocide showed an efficacy similar to Mycoshield, and the biocontrol Actinovate (*Streptomyces lydicus*) also showed promise in some trials (*see* 2009 - 2011 Annual Reports). The fermentation antimicrobial polyoxin-D (organic formulation) and combinations of Cerebrocide and polyoxin-D were also effective. The biocontrol Blossom Protect (*Aureobasidium pullulans*) was effective and one of the most consistent biologicals in 2010-2012 trials. Thus, our recent research on organic alternatives is quite promising. Biological controls that have been developed for fire blight in the United States include the registered Blight Ban A506 Biopesticide (*Pseudomonas fluorescens* strain A506), Serenade (fermentation product of *Bacillus subtilis* strain QST 713), as well as Bloomtime Biological FD Biopesticide (*Pantoea agglomerans* strain E325). Unfortunately they have been very inconsistent in their performance. These products are most effective under low inoculum levels and less favorable micro-environments. Thus, among the materials evaluated by us, the antibiotic kasugamycin (Kasumin) is the most promising new material for managing fire blight in California. Still, biologicals like Actinovate, Blossom Protect, and the newly registered product Double Nickel 55 (*Bacillus amyloliquefaciens*), as well as natural products (Cerebrocide and polyoxin-D – recently exempt from tolerance by the US-EPA) should continue to be evaluated again in 2013. The toxicity of antibiotics used in fire blight control against new biocontrols has to be continued to be evaluated as in 2013 to determine incompatibilities that could prevent their use in mixture programs.

Our goal is to develop highly effective rotational programs starting with copper and/or antibiotics mixed with fungicides during bloom followed by mixtures or rotational treatments of fungicides and antibiotics or potentially SAR compounds as cover sprays during early fruit development. With the detection of isolates of *E. amylovora* with reduced sensitivity to oxytetracycline, and the yearly fluctuations in incidence of streptomycin resistance we will need to continue our surveys and monitoring programs, as well as conduct molecular characterization of resistant strains.

We are also planning to explore a new strategy for the management of fire blight that includes the use of sanitizing agents and novel chemistries that inhibit biofilm formation. Our experience from working with other crops has shown us that some sanitizing treatments can effectively inactivate bacterial contamination on wounded and non-wounded plant surfaces (something that other sanitizers such as bleach cannot do). We plan to use these treatments as a field application to inactivate epiphytic populations of *E. amylovora* during bloom time and these treatments could be followed by a secondary treatment, possibly with a biocontrol agent that then potentially could more effectively colonize the blossom tissues (no competition from other organisms in the phylloplane). Biofilms are produced by the pathogen and are thought to help protect bacteria from harsh environments. By inhibiting biofilms and by keeping bacteria in a planktonic state (single cell state), they may be more sensitive to chemical treatments (Worthington et al. 2012). Thus, we plan to evaluate biofilm inhibitors in combination with low MCE compounds, antibiotics (e.g., Kasumin), and other products in mixtures or rotations to optimize in-season applications.

Management of postharvest decays. Apples like other pome fruit can be stored for some period of time using the correct storage environments. Still, postharvest decays caused by fungal organisms can cause crop losses that are economically detrimental to storing and marketing of fruit. The major postharvest pathogens of apples include *Penicillium expansum, Botrytis cinerea, Alternaria alternata, Mucor piriformis,* and *Neofabraea* spp. causing blue mold, gray mold, black mold, Mucor decay, and bull's eye rot, respectively. Thiabendazole (TBZ) has been the main postharvest fungicide available for pome fruit for the last 35 years. Unfortunately, with extensive usage, TBZ-resistant populations of *Penicillium* and *Botrytis* spp. have developed and are commonly found in packinghouse storage rooms.

Although fungicides can reduce the incidence of decay when used preharvest, they are most effectively used as postharvest treatments. Through our research, new postharvest fungicides that were registered in recent years include the phenylpyrrole Scholar (fludioxonil) and the anilinopyrimidine Penbotec pyrimethanil), that are both effective against gray mold and blue mold, as well as the hydroxyanilide Judge (fenhexamid) that is only effective against gray mold. Like TBZ, these are all single-site mode of action fungicides that have a high risk for selecting for resistant pathogen populations when used exclusively. Unfortunately, this practice is often the case because pricing and marketing of fungicides with other postharvest treatments (e.g., sanitizers, fruit coatings) are major factors for packinghouse managers. We are continuing our evaluation and support of registration of new materials because not all of the fungicides have the same spectrum of activity against the various decays occurring on pome fruit. Additionally, there is widespread resistance against TBZ in *Penicillium* and *Botrytis* populations. More recently, resistance to pyrimethanil has been reported in both pathogens in packinghouses in the Pacific Northwest. Our laboratory studies also predicted a high resistance potential for pyrimethanil, but also for fludioxonil, and some of the resistant isolates competed well in the presence of sensitive wild-type isolates. Thus, there is not only a risk for resistance to develop against the new fungicides, but also that resistant isolates may displace the sensitive population if selection pressure (e.g., presence of fungicide) persists. Therefore, new materials of different chemical classes are needed to combat resistance development.

In collaboration with the registrant of Scholar, Syngenta Crop Protection, and IR- 4 Specialty Crop Program, over several years we have been evaluating the DMI fungicide difenoconazole as a mix partner for fludioxonil. Difenoconazole is not effective against gray mold, but highly effective against blue mold and also bull's eye rot (that is not controlled with fludioxonil). We have been successful in optimizing usage rates and evaluating several pre-mixture formulations, and these studies need to be finalized. Registration for difenoconazole is expected for 2014. We also plan to evaluate the efficacy of both fungicides in fruit inoculation studies with *Alternaria* species. These fungi were found to be very sensitive against fludioxonil and difenoconazole in in vitro studies.

In 2012 we demonstrated that fruit temperature at treatment time affected the amount of fludioxonil residue of two apple cultivars. When temperature of the treatment solution was lower (i.e., 10C) than the fruit temperature (i.e., 12.5 or 20C), higher residues were obtained as when fruit temperature was lower (i.e., 7.5C). Thus, fruit temperature in relation to treatment temperature is an important parameter for fungicide uptake and additional fruit temperature-treatment temperature combinations could be evaluated, also with other fungicides and using other apple cultivars since there were differences in our 2012 studies between two apple varieties. This information is valuable for the most effective usage of the new fungicides.

In initial studies in 2012, we found that polyoxin-D (Ph-D) was similarly effective to Penbotec in reducing the incidence of gray mold, but it was not effective against blue mold. This compound is also known to be highly effective against *Alternaria* species. Polyoxin-D recently obtained an exempt status and thus, it has the potential to be the most effective organic treatment ever available. Our goal is to continue to evaluate this product for the management of postharvest decays of apples. Additionally, another compound coded Nm-1 has the potential to be used as a postharvest treatment on pome fruit and other crops. The registrant is supporting the fungicide's development on fruit crops and is planning to submit for registration. Nm-1 has been used as a food additive to prevent mold growth, including *Penicillium* species, on dairy products for many years in the United States. The compound has the potential to obtain an exempt status and an organic registration because it is a natural fermentation product. Furthermore, over all the years in use, resistance in *Penicillium* species against Nm-1 has not occurred. Thus, we plan to evaluate several very exciting new products for the management of postharvest decays of apples.

Objectives for 2013

Fire blight research

1. Evaluate the efficacy of treatments for managing fire blight and characterize antibiotic resistance.
    A. Laboratory in vitro tests to evaluate the bactericidal activity of antibiotics with and without biofilm inhibitors such as 2-aminoimidazole using spiral gradient dilution assays.
    B. Small-scale hand-sprayer tests using different treatment-inoculation schedules to evaluate bio-film inhibitors in combination with antibiotics and/or low MCE copper products.
    C. Field trials with protective air-blast spray treatments:
        i. New formulations of copper (e.g., Kocide 3000, Badge X2) with and without antibiotics.
        ii. Plant defense activators (e.g, ProAlexin, Actigard, PM-1) with and without antibiotics.
        iii. Evaluate the efficacy of biological controls (e.g., Actinovate, Blossom Protect, Double Nickel 55), and natural products (e.g., Cerebrocide) in integrated programs using antibiotics and low MCE copper products.
    D. Characterization of streptomycin- and oxytetracycline-resistant strains using molecular approaches: characterize plasmids that harbor the resistance genes and compare to *E. amylovora* populations from other parts of the country.

Postharvest research

2. Comparative evaluation of new postharvest fungicides
    A. Evaluate difenoconazole, fludioxonil, and difenoconazole-fludioxonil pre-mixtures at selected rates against gray mold, blue mold, Alternaria decay, and bull's eye rot and compare to pyrimethanil.
    B. Evaluate polyoxin-D and Nm-1 against gray mold, Alternaria decay, and bull's eye rot and compare to pyrimethanil and fludioxonil.
    C. Evaluate treatment effects on fungicide residues on apple fruit – determine the effect of temperature differences between treatment solution and fruit on uptake of fludioxonil and difenoconazole of different apple cultivars.
    D. Determination of baseline sensitivities. Baseline sensitivities for fludioxonil and difenoconazole will be continued to be developed for additional isolates of *Alternaria* spp. that are collected.

Plans and Procedures

Evaluation of 2-aminoimidazole as a biofilm inhibitor and enhancer of toxicants such as antibiotics and copper to* E. amylovora *in in vitro assays and small-scale field trials. Strains of *E. amylovora* that are sensitive kasugamycin, sensitive or resistant to streptomycin (high and moderate resistant strains), and sensitive or resistant oxytetracycline will be evaluated for their sensitivity to each of the three antibiotics with or without the addition of the 2-aminoimidazole. For determination of the in vitro sensitivity, we will use the spiral gradient dilution assay where a chemical concentration gradient is established on nutrient agar in a Petri dish. Suspensions of *E. amylovora* will be plated onto the medium in radial streaks across the concentration gradient. Inhibitory concentrations will be determined using a computer program.

In small-scale field tests in an experimental pear orchard at UC Davis, treatments using a biofilm inhibitor (2- aminoimidazole) in conjunction with antibiotics will be applied to run-off to open blossoms using a hand sprayer. Each replication will consist of one branch on each of four trees. After selected time periods, blossoms will be spray-inoculated with *E. amylovora* (10^6 cfu/ml), inoculated branches will be bagged overnight, and disease will be evaluated based on the number of diseased blossoms per 100 blossoms evaluated per replication. The post-infection activity of treatments will be evaluated by first inoculating blossoms and treating after 24 h.

Field studies on the management of fire blight using protective treatments during the growing season. Air-blast field studies on the relative efficacy of protective treatments will be conducted in an experimental apple orchard at the Kearney AgCenter where fire blight caused crop losses previously. Two applications will be done (at 10-20% and at 60-80% bloom). The relative efficacy of protective treatments of Kasumin (100 ppm) and Selected SAR compounds such as Actigard, ProAlexin, and PM-1 will be used alone or in mixtures with antibiotics to evaluate the effect on efficacy and phytotoxicity. New copper formulations that use a reduced amount of copper including Kocide 3000 (0.5 lb/A) and Badge X2 (0.5-1 lb/A) will also be evaluated. The biological controls Actinovate and Blossom Protect, Double Nickel 55, as well as the biofermentation product polyoxin-D (Ph-D) and Cerebrocide will be evaluated alone or in rotation/mixtures with other treatments to develop integrated programs for resistance management. Incidence of new blight infections on blossoms and leaves in addition to potential phytotoxic effects of the treatments (e.g., fruit russeting caused by copper) will be evaluated. Application timings will be determined based on temperature, rainfall, and host development. Treatments will be replicated four to six times on different trees.

New copper formulations that use a reduced amount of copper including Kocide 3000 (0.5 lb/A) and Badge X2 (0.5-1 lb/A) will also be evaluated. The biological controls Actinovate and Blossom Protect, as well as the biofermentation product polyoxin-D (Ph-D) will be evaluated in rotation/mixtures with other treatments to develop integrated programs for resistance management. Incidence of new blight infections on blossoms and leaves in addition to potential phytotoxic effects of the treatments (e.g., fruit russeting caused by copper) will be evaluated. Application timings will be determined based on temperature, rainfall, and host development. Treatments will be replicated four to six times on different trees.

In small-scale field tests at UC Davis, treatments will be applied to run-off to open blossoms using a hand sprayer. Each replication will consist of one branch on each of four trees. After selected time periods, blossoms will be spray-inoculated with *E. amylovora* (10^6 cfu/ml), inoculated branches will be bagged overnight, and disease will be evaluated based on the number of diseased blossoms per 100 blossoms evaluated per replication. The post-infection activity of treatments will be evaluated by first inoculating blossoms and treating after 24 h. Data for chemical and biological control will be analyzed using analysis of variance and LSD mean separation procedures of SAS 9.1.

Characterization of streptomycin- and oxytetracycline-resistant strains using molecular approaches. Molecular characterization of streptomycin resistance will be continued. For this, the location of the strA-strB genes and of transposon Tn5393 will be determined. Because primers are available that target the resistance genes and the transposon as well as at least three plasmids of *E. amylovora*, PCR will be able to identify the location of the genes if they are associated with any of these plasmids. Additionally, we will determine DNA sequences flanking the resistance genes and transposon and compare these sequences to the database available for *E. amylovora*. This strategy will be helpful if genes are integrated on the chromosome or if new plasmids are involved.

Efficacy of new postharvest fungicides for managing apple decays in storage. Fruit (cvs. Granny Smith and Fuji) will be treated similar to commercial practices concerning harvest, handling, packing, and temperature-management of fruit. Fruit will be wound-inoculated with conidial suspensions of several decay fungi (*B. cinerea, P. expansum, N. perennans*, *Alternaria* sp.) and treated after selected times. For the Nm-1, dip treatments on a smaller scale (3 or 4 replications of 10 fruit) will be done in initial studies to determine the spectrum of activity and effective treatment rates. Nm-1 and the other fungicides (fludioxonil, difenoconazole, pre-mixtures fludioxonil/difenoconazole, and polyoxin-D) will then be evaluated in experimental packing line trials at Kearney Agricultural Center and 20-40 fruit for each of four replications will be used. For the new fludioxonil-difenoconazole pre-mixture, we will compare the efficacy of different application methods (in-line drench, CDA, and T-jet). Treatments will be compared to pyrimethanil. Data will be analyzed using analysis of variance and averages will be separated using least significant difference mean separation procedures of SAS 9.2.

To evaluate the effect of fruit and treatment temperature on fungicide residues, pear fruit will be equilibrated to temperatures of 7.5, 12.5, or 20 C and then dipped for 30 sec in an aqueous solution of fludioxonil or difenoconazole at 10C or 20C. Fruit will then be air dried and processed for residue analysis. Two sets of fruit from each treatment will be used for residue analysis and efficacy data will also be obtained for the treated fruit. For this, four replications of 20 fruit will be used. Data will be analyzed using analysis of variance and averages will be separated using least significant difference mean separation procedures of SAS 9.2.

Determination of baseline sensitivities. Baseline sensitivities for fludioxonil and difenoconazole will be continued to be developed for additional isolates of *Alternaria* spp. that are collected. To date, we have only evaluated 34 with a goal of at least 70. We will use the spiral gradient dilution method that allows for efficient, high throughput evaluation of isolates to determine EC_{50} concentrations.

Benefits to the industry

With the imminent approval of kasugamycin by the US-EPA, tolerances and MRLs for kasugamycin will be established on pome fruit, walnut, and tomato crops. With the limited number of materials available to pome fruit growers, this new active ingredient represents a major step forward for managing fire blight in an integrated approach before resistance develops in the pathogen population. Historically, the overuse of streptomycin led to resistant pathogen populations and the over-reliance of oxytetracycline as a substitute for streptomycin has led to the first detections of oxytetracycline resistance in the pathogen. This information will help to develop integrated programs for using kasugamycin in rotations or mixtures with other antibiotics, fungicides, biologicals, and possibly SAR compounds and new materials (e.g. biofilm inhibitors) that will hopefully minimize the risk for the development of resistant populations of the pathogen to this antibiotic, as well as any new material. Surveys and molecular characterization of streptomycin and oxytetracycline resistance will help to better understand the biology of pathogen populations. Our studies on the molecular characterization of streptomycin and oxytetracycline resistance will provide information on the evolution of resistance mechanisms and how the pathogen responds to selection pressures under field conditions. The lack of equivalent fitness of resistant to wild-type strains indicates that potentially with rotational materials, older antibiotics such as streptomycin can be still used with some degree of effectiveness in management programs. Furthermore, although previous biologicals had an inconsistent performance and their use was restricted to blossom treatments, newer biologicals (e.g., Actinovate, Blossom Protect) are being demonstrated as more consistent.

In comparative efficacy studies in the last several years, the performance of kasugamycin (Kasumin 2L) used at 100 ppm was similar or better to oxytetracycline. Phytotoxicity only occurred at high rates that will be off-label (e.g., 200 ppm). Efficacy data were obtained based on repeated applications of the product used by itself. We plan to use up to 4 applications per season and no more than two sequential applications. The product label will include guidelines for optimal use (e.g. pH and buffers needed), use in rotation or combination with other available treatments including fungicides (e.g., mancozeb, new low MCE copper products) and possibly new biological controls, SAR compounds, or even biofilm inhibitors that hopefully will enhance the performance and minimize the development of resistant strains of the pathogen. Furthermore, the performance of biological treatments can be possibly improved when used in combination with a sanitizing treatment as suggested in this proposal.

For the packer, the challenge is to develop management programs using new fungicides for control of gray mold, blue mold, Alternaria rot, and other decays of apple. The challenge to the industry is to store fruit and provide decay-free, wholesome fruit to local and distant markets. For this, fungicide management programs have to be developed and continually adapted for control of gray mold, blue mold, and other decays of apple based on new fungicides that are replacing or supplementing the previous postharvest standard TBZ (Mertect) and allow rotations to prevent selection of resistance in postharvest fungal pathogens. The development of several effective postharvest fungicide treatments, especially of a pre-mixture, and the development of other resistance strategies have the potential to greatly decrease losses of fruit from various decays during storage in a durable program that will be effective for many years. Baseline sensitivities that we are establishing in pathogen populations will facilitate the early detection and prevent the spread of resistance. Another critical aspect to this goal is improving application methods such as using postharvest re-circulating in-line drenches. Thus, information from this research directly benefits growers and packers by identifying and registering new materials, as well as development of improved handling practices for control of postharvest diseases of apples.

References

1. Adaskaveg, J.E., Förster, H., and Wade, M.L. 2011. Effectiveness of kasugamycin against *Erwinia amylovora* and its potential use for managing fire blight of pear. Plant Dis. 95: 448-454.
2. Burr, T. J. et al. 1993. Streptomycin-resistant bacteria associated with fire blight infections. Plant Dis. 77: 63-66.
3. Van Der Zwet, T. and Keil, H.L. 1979. Fire Blight - A Bacterial Disease of Rosaceous Plants. United States Department of Agriculture, Handbook No. 510. 200 pp.
4. Vanneste, J. (ed.). 2000. Fire Blight: The Disease and its Causative Agent, *Erwinia amylovora*. CAB International, Oxford. 384 pp.

Budget Request:
Budget Year: 2013.
Funding Source: Apple Commission of California

Salaries and Benefits:	Post-Docs/RAs		5,000
	Lab/Field Ass't		2,500
	Subtotal		7,500
	Employees' Benefits		3,500
		Subtotal	11,000
Supplies and Expenses*			3,000
Equipment			0
Operating Expenses/Equipment Travel (Davis Campus only)			0
Travel			2,000
Department Account No. ________		**Total**	**16,000**

*** -** Costs include expenses of $2000 for maintaining an apple orchard at the Kearney AgCenter.

Originator's Signature J.E. Adaskaveg Date: 2-15-13

Department Chair Katherine Borkovich Date: 2-15-13

Liaison Officer ____________________ Date:________

CALIFORNIA BLUEBERRY

PROJECT PLAN / RESEARCH GRANT PROPOSAL

Work group / Department: USDA-ARS-SJVASC, Crop Protection and Quality Unit

Project Year: 1 (2012) Anticipated Duration of Project: 2 years

Project Title: The postharvest fumigation of California blueberries to eliminate insects with potential to serve as export trade barriers

Principle Investigator: Spencer S. Walse

USDA-ARS-SJVASC, 9611 S. Riverbend Ave, Parlier, CA 93648,
(559) 596-2750, fax (559) 596-2792, spencer.walse@ars.usda.gov

Cooperating Investigators:

Steve Tebbets, USDA-ARS-SJVASC, (559) 596-2723, steve.tebbets@ars.usda.gov

Current 2012 Funding Request: $20,417

BACKGROUND/JUSTIFICATION

The spotted wing drosophila, *Drosophila suzukii* (Matsumura), is a pest of serious concern to western U.S. blueberry producers and shippers, as it has been found in key production regions along the Pacific coast. The brown marmorated stink bug (BMSB) is very likely to be a pest of concern to certain countries that import blueberries from California USA. Although the economic consequence(s) of these pests are unknown, a quantitative confirmation of postharvest methyl bromide (MB) and phosphine (PH3) treatments will be conducted to prove that they can be eliminated from marketing channels. The APHIS MB T101i-1 blueberry import schedule (T > 70 °F, 2lbs /1000ft^3, 3h) will serve as an initial benchmark for control; schedule development will then graduate toward conditions recommended by industry for blueberry export from CA (47 < T < 70 °F, 2-4lbs /1000ft^3, 2-3 h). In addition, low-temperature (33 – 42 °F) phosphine fumigations will also be conducted; this type of fumigation has the advantage of not requiring the cold-chain of fruit storage to be broken, thereby increasing the chance of decay and phytotoxicity. It should be noted that cold-treatments can also be effective and will be explored; however, the time required for treatment (ca. 5-22 day) make this type of treatment undesirable in many marketing scenarios including exports.

Long-term research goal. The overreaching goal of this project is to ensure pest-free blueberries are channeled to markets.

Short-term research goal. Prove that postharvest MB and phosphine fumigation schedules can be used to eliminate SWD and BMSB from California blueberries.

2012 OBJECTIVES:

This project is planned in phases as indicated below. Each phase will have its own goals and these goals will feed those of the following phase. A timeline for each phase will be established when the research commences.

Phase I. Establish a colony of SWD at the USDA-ARS SJVASC in Parlier, CA as well as a colony of BMSB at the Contained Research Facility at University of California at Davis with the throughput necessary to routinely conduct fumigation studies.

Timeline: Already accomplished.

Year 1 (2012) – MB & PH3: laboratory scale.

Phase II. Determine mortality of SWD eggs and larvae in infested blueberries, as well as, pupae and adults in cages to MB in 1ft^3 chambers at 43, 50, 60, and 70 °F. Determine mortality of BMSB nymphs (1st-5th instars), and adults in 1ft^3 chambers at over same temperatures. Establish and report dose-mortality regressions with statistical validity to establish most fumigant-tolerant life stage of each species (Probit v. 2007 software).

Phase III. Determine the mortality of PH3 as well as PH3-oxygen mixtures to eggs and larvae in infested blueberries, as well as, pupae and adults in cages in 1ft^3 chambers at 35 °F. Determine mortality of BMSB nymphs (1st-5th instars), and adults in 1ft^3 chambers at same temperature. Establish and report dose-mortality regressions with statistical validity to establish most fumigant-tolerant life stage of each species (Probit v. 2007 software).

Phase VI. A blueberry postharvest quality evaluation will be performed to identify any potential phytotoxicity that occurs from MB as well as PH3 exposure at dosages that are efficacious for killing the most tolerant life stage of SWD and BMSB. (While the SJVASC does have personnel with expertise in this area, this evaluation can be done by whomever is recommended by industry). These evaluations will be used to guide the optimization of treatment paramenters from both a toxicological (maximization) and phytotoxicological (minimization) perspective.

Phase V. Quantify residues that result from exposure to MB, PH3, and PH3-oxygen mixtures at dosages efficacious against the most tolerant stage of each species in commercial trials.

Phase VI. Optimize the PH3-oxygen mixture to control the most tolerant stage of each species in as short a treatment time as possible at 35 °F.

2013 OBJECTIVES (planned)

Year 2 – MB & PH3: confirmatory scale.

Phase II. Perform confirmatory MB fumigations in triplicate 9 1ft^3 chambers with 10,000 SWD specimens and 3,000 BMSB (most tolerant stage of each) while fruit is packed as recommended by industry. To ensure adequate exposure for complete mortality, fumigant concentrations will be measured throughout fumigations. Sorption and box effects on fumigation will be quantitatively analyzed and reported.

Phase III. Perform confirmatory PH3 as well as PH3-oxygen mixture fumigations in triplicate 9 1ft^3 chambers with 10,000 SWD specimens and 3,000 BMSB (most tolerant stage of each) while fruit is packed as recommended by industry. To ensure adequate exposure for complete mortality, fumigant concentrations will be measured throughout fumigations. Sorption and box effects on fumigation will be quantitatively analyzed and reported.

Phase IV. Document phytotoxicity that occurs from MB and PH_3 exposure at dosages that are efficacious for killing the most tolerant stage of each species in confirmatory trials.

2012 BUDGET REQUEST

Salaries and Benefits

GS-3 Lab Assistant (50%):		15,344

Supplies and Expenses

rearing		1,000
fumigants		500
travel		2,000
	Subtotal:	$18,394
USDA-ARS overhead (11.1%)		2,023
	Total:	$20,417

2013 BUDGET PROJECTION *(confirmatory testing)* $15,000

USDA-ARS PI Walse 2012-2013 research update

Project: “Systems-based strategies for postharvest insect control: Mortality and removal of Light Brown Apple Moth, Codling Moth, Brown Marmorated Stink Bug, and other insect pests in California apples during packing and export”

Completed and/or in progress objectives:

Phase 1 (Yr. 1, 2012). Objective 1. A commercial-scale Berlese funnel trap will be constructed. Leaf debris will be collected from 1) the QA-QC inspection stations at the end of export packing lines, and 2) beneath grating/fall-outs as field bins are dumped. Insects that emerge from leaf debris will be identified and reported (to CAC only) relative to the mass of debris collected as related to production levels. Our findings will be compared to public records collected by academics as well as county and state inspection officers.

Objective 2. Insects will be exposed to elements of postharvest processing individually and in series; statistically robust data on removal and/or mortality will be generated. Specifically, LBAM eggs will be deposited on leaves that will then be traced through a packing operation (performed at UC Kearney). BMSB life stages will be placed on fruit and leaves and traced through a packing operation (performed in West Virginia).

Brief. Commercial protocols for cleaning and packing California apples were being used to demonstrate that the probability that BMSB, OFM, and CM life stages occur on leaf debris. In addition, a toxicological response of all life stages of the selected species to forced-air used in a commercial wax dryer at 128 ± 10°F was generated. The cumulative effect of consecutive postharvest cleaning and packing events will be reported in the context of evaluating “systemic” joint probabilities of insect removal and mortality prior to the entrance of fruit into export marketing channels.

Studies last season focused on collecting leaf debris from a packing line, infesting it with all life atges of OFM and CM, and then incubating until adult emergence. This data is used to diagnose the efficiency of our incubation and analysis techniques, which will enable the quantification of removal/mortality probabilities. Regression models predict Probit 9 level mortality (99.9968%) of the most heat-tolerant OFM and CM life stages after ≥ 4.6 min in a commercial wax dryer.

All tests will be repeated for BMSB this season, as the colony maintained at the Contained Research Facility at UC Davis is thriving. Results on leaf-debris study will be analyzed and reported.

CALIFORNIA APPLE COMMISSION

PROJECT PLAN / RESEARCH GRANT PROPOSAL

Work group / Department: USDA-ARS-SJVASC, Crop Protection and Quality Unit

Project Year: 1 (2012) Anticipated Duration of Project: 2 year

Systems-based strategies for postharvest insect control: Mortality and removal of Light Brown Apple Moth, Coddling Moth, Brown Marmorated Stink Bug, and other insect pests in California apples during packing and export

Project Leader:

Spencer S. Walse: USDA-ARS-SJVASC, 9611 S. Riverbend Ave, Parlier, CA 93648, (559) 596-2750, fax (559) 596-2792, spencer.walse@ars.usda.gov

Cooperating Individuals (alphabetical):

Steve Tebbets, USDA-ARS-SJVASC, 9611 S. Riverbend Ave, Parlier, CA 93648, (559) 596-2723, steve.tebbets@ars.usda.gov

Current Funding Request: $7,345

BACKGROUND/JUSTIFICATION

Insect pests, such as the Light Brown Apple Moth (LBAM), coddling moth (CM), and oriental fruit moth (OFM) are an economic concern to California (CA) apple growers and shippers when found in production regions. Perhaps more important than losses caused by leaf defoliation/herbivory and superficial damage to fruit, is the economic threat insects pose as trade barriers. At any time, importing countries can confront industry with quarantine and/or treatment requirements with the potential to terminate, or at least inhibit, trade. Research on postharvest insect "control" is needed to retain the ability of CA to continue exporting apples when an importing country raises concerns regarding the potential for insects to enter, establish, and spread via CA imports.

Long-term research goal. The overreaching goal of this project is to ensure pest-free apples are channeled to markets.

Short-term research goal. Reduce the need for (and efficacy requirements of) standalone fumigations by developing systems-based approaches to demonstrate the removal and/or mortality of insects as fruit is harvested, cleaned, packed, and shipped using the commercial methods employed by California industry.

2012 OBJECTIVES:

In general, research is planned in compounding phases as indicated below with corresponding objectives.

Phase I (Yr. 1, 2012).

Objective 1. A commercial-scale Berlese funnel trap will be constructed. Leaf debris will be collected from 1) the QA-QC inspection stations at the end of export packing lines, and 2) beneath grating/fall-outs as field bins are dumped. Insects that emerge from leaf debris will be identified and reported (to CAC only) relative to the mass of debris collected as related to production levels. Our findings will be compared to public records collected by academics as well as county and state inspection officers.

Timeline: Trap has been constructed; Debris will be collected throughout 2012 production season.

Objective 2. Insects will be exposed to elements of postharvest processing individually and in series; statistically robust data on removal and/or mortality will be generated. Specifically, LBAM eggs will be deposited on leaves that will then be traced through a packing operation (performed at UC Kearney). BMSB life stages will be placed on fruit and leaves and traced through a packing operation (performed in West Virginia).

Timeline: Run throughout 2012 apple production season and into winter.

2013 OBJECTIVES: Phase II (Yr. 2, 2013). Objective 1. Continue with the "systems-based" postharvest packinghouse/processing investigation and build on 2012 results. Objective 2. Integrate field trapping, IPM, and pesticide use pattern results with postharvest systems-based approach to generate statistical framework to quantify reduction in risk from an insect pest as product moves from production areas through packing operations toward export markets.

2012 BUDGET REQUEST

Expenses		
GS-3 Lab Assistant (20%):		3,368
travel		250
supplies		500
rearing		500
postharvest analysis		2,000
	Subtotal:	$ 6,610
USDA-ARS overhead (11.1%)		735
	Total:	$7,345

USDA-ARS PI Walse 2012-2013 research update

Project: "Systems-based strategies for postharvest insect control: Mortality and removal of Light Brown Apple Moth, Codling Moth, Brown Marmorated Stink Bug, and other insect pests in California apples during packing and export"

Completed and/or in progress objectives:

Phase 1 (Yr. 1, 2012). Objective 1. A commercial-scale Berlese funnel trap will be constructed. Leaf debris will be collected from 1) the QA-QC inspection stations at the end of export packing lines, and 2) beneath grating/fall-outs as field bins are dumped. Insects that emerge from leaf debris will be identified and reported (to CAC only) relative to the mass of debris collected as related to production levels. Our findings will be compared to public records collected by academics as well as county and state inspection officers.

Objective 2. Insects will be exposed to elements of postharvest processing individually and in series; statistically robust data on removal and/or mortality will be generated. Specifically, LBAM eggs will be deposited on leaves that will then be traced through a packing operation (performed at UC Kearney). BMSB life stages will be placed on fruit and leaves and traced through a packing operation (performed in West Virginia).

Brief. Commercial protocols for cleaning and packing California apples were being used to demonstrate that the probability that BMSB, OFM, and CM life stages occur on leaf debris. In addition, a toxicological response of all life stages of the selected species to forced-air used in a commercial wax dryer at 128 ± 10°F was generated. The cumulative effect of consecutive postharvest cleaning and packing events will be reported in the context of evaluating "systemic" joint probabilities of insect removal and mortality prior to the entrance of fruit into export marketing channels.

Studies last season focused on collecting leaf debris from a packing line, infesting it with all life atges of OFM and CM, and then incubating until adult emergence. This data is used to diagnose the efficiency of our incubation and analysis techniques, which will enable the quantification of removal/mortality probabilities. Regression models predict Probit 9 level mortality (99.9968%) of the most heat-tolerant OFM and CM life stages after ≥ 4.6 min in a commercial wax dryer.

All tests will be repeated for BMSB this season, as the colony maintained at the Contained Research Facility at UC Davis is thriving. Results on leaf-debris study will be analyzed and reported.

CALIFORNIA APPLE COMMISSION

PROJECT PLAN / RESEARCH GRANT PROPOSAL

Work group / Department: USDA-ARS-SJVASC, Crop Protection and Quality Unit

Project Year: 1 (2012) Anticipated Duration of Project: 2 year

Systems-based strategies for postharvest insect control: Mortality and removal of Light Brown Apple Moth, Coddling Moth, Brown Marmorated Stink Bug, and other insect pests in California apples during packing and export

Project Leader:

Spencer S. Walse: USDA-ARS-SJVASC, 9611 S. Riverbend Ave, Parlier, CA 93648, (559) 596-2750, fax (559) 596-2792, spencer.walse@ars.usda.gov

Cooperating Individuals (alphabetical):

Steve Tebbets, USDA-ARS-SJVASC, 9611 S. Riverbend Ave, Parlier, CA 93648, (559) 596-2723, steve.tebbets@ars.usda.gov

Current Funding Request: $7,345

BACKGROUND/JUSTIFICATION

Insect pests, such as the Light Brown Apple Moth (LBAM), coddling moth (CM), and oriental fruit moth (OFM) are an economic concern to California (CA) apple growers and shippers when found in production regions. Perhaps more important than losses caused by leaf defoliation/herbivory and superficial damage to fruit, is the economic threat insects pose as trade barriers. At any time, importing countries can confront industry with quarantine and/or treatment requirements with the potential to terminate, or at least inhibit, trade. Research on postharvest insect "control" is needed to retain the ability of CA to continue exporting apples when an importing country raises concerns regarding the potential for insects to enter, establish, and spread via CA imports.

Long-term research goal. The overreaching goal of this project is to ensure pest-free apples are channeled to markets.

Short-term research goal. Reduce the need for (and efficacy requirements of) standalone fumigations by developing systems-based approaches to demonstrate the removal and/or mortality of insects as fruit is harvested, cleaned, packed, and shipped using the commercial methods employed by California industry.

2012 OBJECTIVES:

In general, research is planned in compounding phases as indicated below with corresponding objectives.

Phase I (Yr. 1, 2012).

Objective 1. A commercial-scale Berlese funnel trap will be constructed. Leaf debris will be collected from 1) the QA-QC inspection stations at the end of export packing lines, and 2) beneath grating/fall-outs as field bins are dumped. Insects that emerge from leaf debris will be identified and reported (to CAC only) relative to the mass of debris collected as related to production levels. Our findings will be compared to public records collected by academics as well as county and state inspection officers.

Timeline: Trap has been constructed; Debris will be collected throughout 2012 production season.

Objective 2. Insects will be exposed to elements of postharvest processing individually and in series; statistically robust data on removal and/or mortality will be generated. Specifically, LBAM eggs will be deposited on leaves that will then be traced through a packing operation (performed at UC Kearney). BMSB life stages will be placed on fruit and leaves and traced through a packing operation (performed in West Virginia).

Timeline: Run throughout 2012 apple production season and into winter.

2013 OBJECTIVES: Phase II (Yr. 2, 2013). Objective 1. Continue with the "systems-based" postharvest packinghouse/processing investigation and build on 2012 results. Objective 2. Integrate field trapping, IPM, and pesticide use pattern results with postharvest systems-based approach to generate statistical framework to quantify reduction in risk from an insect pest as product moves from production areas through packing operations toward export markets.

2012 BUDGET REQUEST

Expenses

GS-3 Lab Assistant (20%):		3,368
travel		250
supplies		500
rearing		500
postharvest analysis		2,000
	Subtotal:	$ 6,610
USDA-ARS overhead (11.1%)		735
	Total:	$7,345

Project: "The postharvest fumigation of apples with phosphine-oxygen mixtures at cold-storage temperature to eliminate the codling moth from export channels."

Completed and/or in progress objectives:

Note we have also been testing oriental fruit moth (OFM) in Phase I and II.

Phase I (Year 1). Establish and maintain a colony of codling moth (CM) in Parlier, CA with the throughput necessary to routinely conduct fumigation studies.

Phase II (Year 1). Determine the mortality of Phosphine-oxygen mixtures to eggs, larvae, diapausing larvae, pupae, and adults of CM in 1 ft^3 chambers at 35 °F. Report dose-mortality regressions with statistical validity (Probit v.2007 software) to establish most tolerant life stage.

Brief. Two formulations of Phosphine gas (PH_3) produced by Cytec Industries, Inc. were tested to determine comparative dose-responses related to the stages of development of CM and OFM. The formulation of PH_3 reported herein was VAPORPH$_3$OS®, which is comprised of ≤ 1.8% PH_3, with balance nitrogen (N_2). The second formulation was ECO$_2$FUME®, which is 2% PH_3, with balance carbon dioxide (CO_2). Results obtained from ECO$_2$FUME® will be reported separately at a later date.

Concentration of PH_3 was held constant at 1000 ppm. Time of exposure and temperature were the primary and secondary variables. The following table shows the scheme of experiments conducted as a "range-finder" series, used to begin to establish the dose-response curves for each species and stage of test insect.

Phase I: Range-Finder Series

Number of Days Exposure at Selected Temperatures (F)

34F	40F	50F	60F	70F
0	0	0	0	0
1	1	1	1	1
2	2	2	2	2
3	3	3	3	
4	4	4		

Test insects included codling moth (CM) and oriental fruit moth (OFM). Preliminary experiments were conducted with all stages of development of the test insects to determine the most tolerant stage(s) of development for each spp: E = egg, L = larva, DL = diapausing larva, P = pupa, and A = adult. Shaded area indicates the tests that need to be completed.

Data showed that the most tolerant stage(s) were egg and pupa for both species tested. It appears that 2-3 day exposures will be required using 1000ppm VAPORPH$_3$OS® at temperature of 34 °F. Confirmatory tests are planned for this season; however, the major research goal for the coming season is to reduce the time required for successful treatment.

CALIFORNIA APPLE COMMISSION

PROJECT PLAN / RESEARCH GRANT PROPOSAL

Project Year: 1 (2012) Anticipated Duration of Project: 2 years

The postharvest fumigation of apples with phosphine-oxygen mixtures at cold-storage temperature to eliminate the coddling moth from export channels.

Principle Investigator: Spencer S. Walse

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Cooperating Investigators:

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David Obenland, USDA-ARS-SJVASC, (559) 596-2801, david.obenland@ars.usda.gov

Current Funding Request: $12,472

BACKGROUND/JUSTIFICATION

Coddling moth (CM) is of economic concern to western U.S. apple producers and shippers. Methyl bromide (MB) fumigations have traditionally been used for the postharvest control of these pests; however, the cold-chain of fruit storage must be broken to achieve required efficacy, thereby increasing the chance of decay and phytotoxicity. Cold-treatments can also be effective; however, the time required for treatment (ca. 5-22 day) as well as the capacity of cooling infrastructure make this type of treatment undesirable, at least to most in California industry who desire to quickly move the most profitable fruit to export markets.

Recent research in our lab indicates that fumigation using phosphine-oxygen mixtures resulted in complete control of an internal feeding fruit fly pest in table grapes at 34ºF in < 24h exposures. No deterioration in quality was observed.

The goal of this project is to tailor this new phytosanitary treatment to target pests of interest to the apple industry.

OBJECTIVES:

This project is planned in phases as indicated below. Each phase will have its own objective and these objectives will feed those of the following phase.

Phase I (Year 1). Establish and maintain a colony of CM in Parlier, CA with the throughput necessary to routinely conduct fumigation studies.

Timeline: Already accomplished.

Phase II (Year 1). Determine the mortality of phosphine-oxygen mixtures to eggs, larvae, diapausing larvae, pupae, and adults of CM in $1ft^3$ chambers at 35 °F. Report dose-mortality regressions with statistical validity (Probit v. 2007 software) to establish most tolerant life stage.

Timeline: June-September 2012

Phase III (Year 1). Perform preliminary studies on residues and phytotoxicity that results from fumigation with phosphine-oxygen mixtures at dosages that are efficacious for killing the most tolerant stage of the CM.

Phase IV (Year 1). Optimize the phosphine-oxygen mixture to control the most tolerant CM lifestage in as short a treatment time as possible at 35 °F.

Timeline: Fall 2012 - Spring 2013

Phase V (Year 2). Perform a confirmatory fumigation in 9 $1ft^3$ chambers at 35 °F with 10,000 CM specimens (most tolerant stage) while fruit is packed in export boxes recommended by industry. To ensure adequate exposure for complete mortality, gas concentrations will be measured throughout load over the course of the fumigation. Sorption and box effects will be quantitatively analyzed and reported.

Timeline: Spring - Fall 2013

Phase VI (Year 2). Document phytotoxicity (Dr. Obanland) that occurs from exposure to phosphine-oxygen mixtures at dosages that are efficacious for killing the most tolerant stage of CM in commercial trials.

Timeline: Concurrent with Phase V

Phase VII (Year 2). Quantify residues in apples that result from exposure to phosphine-oxygen mixtures at dosages efficacious against the most tolerant stage of CM in commercial trials.

Timeline: Concurrent with Phase V & VI.

BUDGET REQUEST (2012)

Supplies and Expenses

GS-3 Lab Assistant (30%):		6,736
rearing		1,500
gas		500
commodities		2,000
travel		500
	Subtotal:	$11,236
USDA-ARS overhead (11.1%)		1,236
	Total:	$12,472

PESTS, DISEASE & STANDARDIZATION

PESTS, DISEASE AND STANDARDIZATION

In 2011, the California Department of Food and Agriculture agreed to the Commission's request and officially repealed the mandatory standard. As a result, the industry was able to harvest Granny Smith apples based on the market and not a subjective test.

In 2012, the California Apple Commission received an additional grant to study the economic impact of the removal of the starch iodine standard. The study is included. Based on the results, and thanks to the California Apple Commission, the removal of the standard has saved the industry $18.7 million. Prior to the removal of the standard it is estimated that the industry lost nearly $18.7 million or approximately $1 per box over the 13-year period.

Economic Impact of Removing the Maturity Standard for California Granny Smith Apples

Prepared by

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August 6, 2013

Table of Contents

Introduction

The California Apple Commission (CAC) represents the state's growers and handlers of fresh apples. The Commission pursues multiple objectives, including market development, education, and research. The CAC also interacts with policymakers and regulatory agencies on issues pertaining to the California apple industry.

Acting on the request of its Board of Directors, the CAC engaged with the California Department of Food and Agriculture (CDFA) to repeal the maturity standard for California Granny Smith apples, which had been in place since 1994. The standard was repealed in time for the 2011/2012 crop year.

In November 2012, CAC retained the services of D.W. Block Associates, LLC (DWB) to estimate the economic impact of removing the maturity standard. This was part of a larger initiative that dealt with other aspects of the standard, such as its relationship with consumer taste preferences.

The study was conducted between October 2012 and July 2013 and consisted of a review of the economic literature, acquisition and processing of data, and an econometric analysis, the results of which are contained in this final report.

The principal investigators for this study were James Ahern, Ph.D., Associate Consultant, Agricultural Economic Analysis & Market Research, and Kyle Birchard, Senior Research Associate with D.W. Block Associates, LLC.

Acknowledgements

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Executive Summary

Following are the three key findings of the study:

1. **Results of the econometric model presented in this study indicate that, for nine of 13 crop years, Granny Smith sellers would have obtained additional revenues in the absence of a maturity standard.**

   The results from the pricing model developed in this study suggest that the early-season premium obtained by California shippers would have been maintained in the absence of the maturity standard. Higher revenues would have been obtained due to a longer shipping period and an overall higher price level for Granny Smiths over the duration of the season.

2. **Model results show that, from 1998 to 2010, the California Granny Smith maturity standard could have delayed the start of shipments by up to five weeks in some years.**

   By prohibiting the shipment of *any* Granny Smiths from a county until the maturity standard was met, marketable fruit was likely kept out of the market. While this is an intuitive finding, without explicit data it is difficult to estimate the likely effect of the standard on shipment patterns, pricing, and revenues. This study appears to be the first to attempt to estimate the magnitude of the effect.

3. **The effect of the Granny Smith maturity standard on California industry revenues is estimated at a negative $18.7 million over the 13 years for which data were available.**

   The maturity standard is estimated to have reduced industry revenues in nine of 13 years and increased revenues in four years.

   With over 18.4 million boxes of Granny Smiths shipped between the 1998 and 2010 seasons, this figure corresponds to a loss of approximately $1.01 per box on average over the 13-year period.

These results are summarized in **Table ES1**, on the following page.

Table ES1: Cumulative Effect of California GS Maturity Standard on Industry Revenues, 1998-2012 (2012 Dollars).

Crop Year	Actual Revenue	Estimated Revenue w/o Maturity Std	Effect of Maturity Standard	Actual Boxes	Effect/Box
1998/99	$29,965,469	$29,678,339	$741,702	1,116,498	$0.26
1999/00	$29,379,099	$32,926,950	($3,447,322)	1,661,708	($2.14)
2000/01	$34,137,052	$33,554,262	($124,296)	1,373,057	$0.42
2001/02	$24,683,113	$28,453,905	($3,583,155)	1,226,123	($3.08)
2002/03	$54,566,273	$55,338,107	($738,573)	2,038,501	($0.38)
2003/04	$42,819,834	$43,546,009	($1,428,568)	1,917,234	($0.38)
2004/05	$25,387,337	$27,455,642	($2,478,267)	1,522,188	($1.36)
2005/06	$32,664,615	$32,011,003	$267,985	1,651,577	$0.40
2006/07	$35,345,227	$37,155,636	($2,160,492)	1,617,379	($1.12)
2007/08	$18,539,934	$20,953,566	($2,756,873)	944,772	($2.55)
2008/09	$43,732,151	$45,368,763	($2,232,801)	1,552,127	($1.05)
2009/10	$14,651,029	$14,552,716	($241,227)	839,175	$0.12
2010/11	$17,502,093	$21,059,789	($3,485,658)	948,167	($3.75)
2011/12*	$31,875,906			1,113,778	
2012/13*	$27,674,770			751,244	
Total	**403,373,226**	**422,054,688**	**($18,681,462)**	**18,408,506**	**($1.01)**

**2011/12 and 2012/13 revenues and boxes omitted from total.*

*   *   *   *   *

Profile of the U.S. Granny Smith Market

Production and Consumption Trends

California and Washington are by far the largest U.S. producers of Granny Smiths, so much so that government and industry sources do not break out Granny Smith production for other states. While imports from southern hemisphere producers are estimated to make up a larger proportion of Granny Smith supply than California production, this does not overlap much, if at all, with California. In addition, data at the level of detail considered here are scarce for imports. **Therefore, the analysis focuses exclusively on the U.S. domestic market supplied by Washington and California**.

A six-year history of the domestic U.S. supply of Granny Smiths is shown in **Table 1**, below. Washington and California supply were taken from industry reports from their respective states; supply from Chile and other countries were calculated by multiplying U.S. imports from each country by the share of Granny Smiths compared to all apples grown in that country.

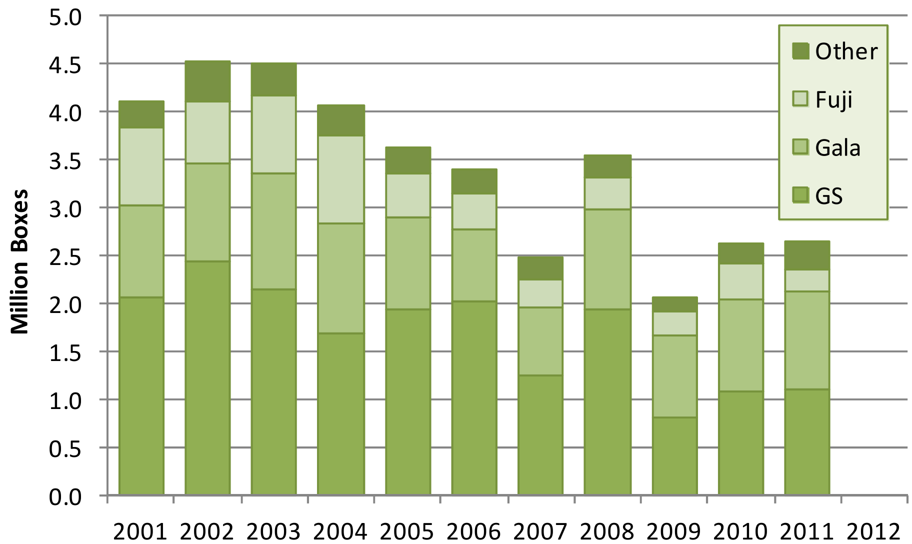
Table 1: Estimated U.S. Domestic Granny Smith Supply by Source (Thousand Boxes).

	2007	2008	2009	2010	2011	2012
Washington	12,847	14,577	12,684	13,004	12,950	n/a
California	945	1,552	839	948	989	n/a
Imports from Chile	1,627	1,222	1,145	1,521	1,103	1,480
Other imports	383	274	348	342	451	492
Total U.S. Supply	15,802	17,625	15,016	15,815	15,493	n/a
CA % of Total	*6%*	*9%*	*6%*	*6%*	*6%*	*n/a*

Sources: Yakima Valley Growers-Shippers Association, California Apple Commission, World Apple and Pear Association, U.S. International Trade Commission, DWB estimates

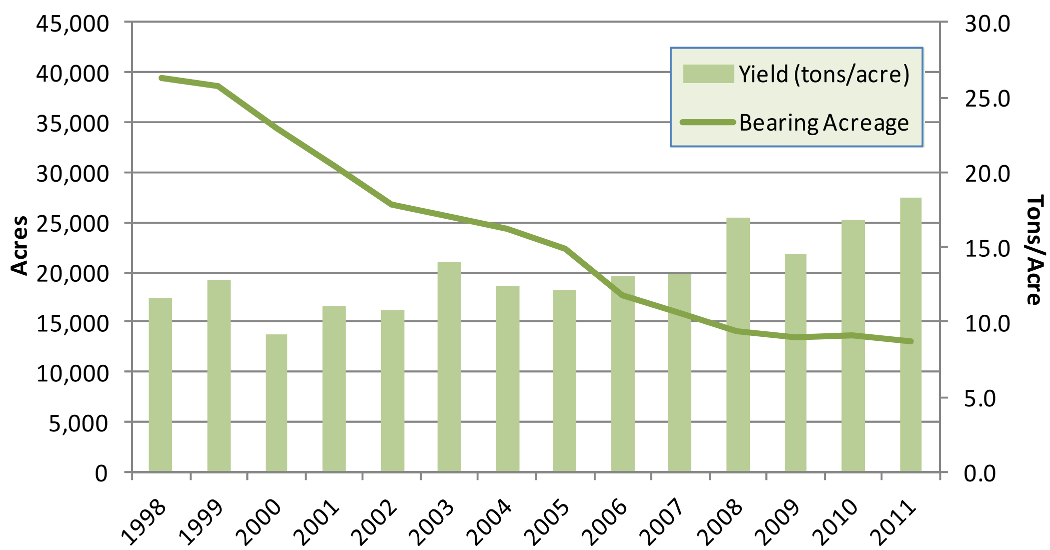
California Granny Smith production has experienced a long-term decline over the past ten years, reflecting similar trends in several other apple varieties grown in the state. California's end-of-season pack-out figures are reported in **Figure 1**, below. Since the 2001 crop year, Granny Smiths have accounted for as much as 60 percent of the state's total apple shipments (in 2006) and as little as 39 percent (in 2009). While acreage data are not reported by variety, California has also experienced a drop in bearing acreage for all apples, which declined from 40,000 acres in 1998 to 13,000 acres in 2011, a trend illustrated in **Figure 2**, below (note also the steady increase in yields over this period).

Figure 1: California Apple Pack-Out, 2001-2011.



Source: California Apple Commission

Figure 2: California Apple Bearing Acreage and Yield, 1998-2011 (All Varieties).



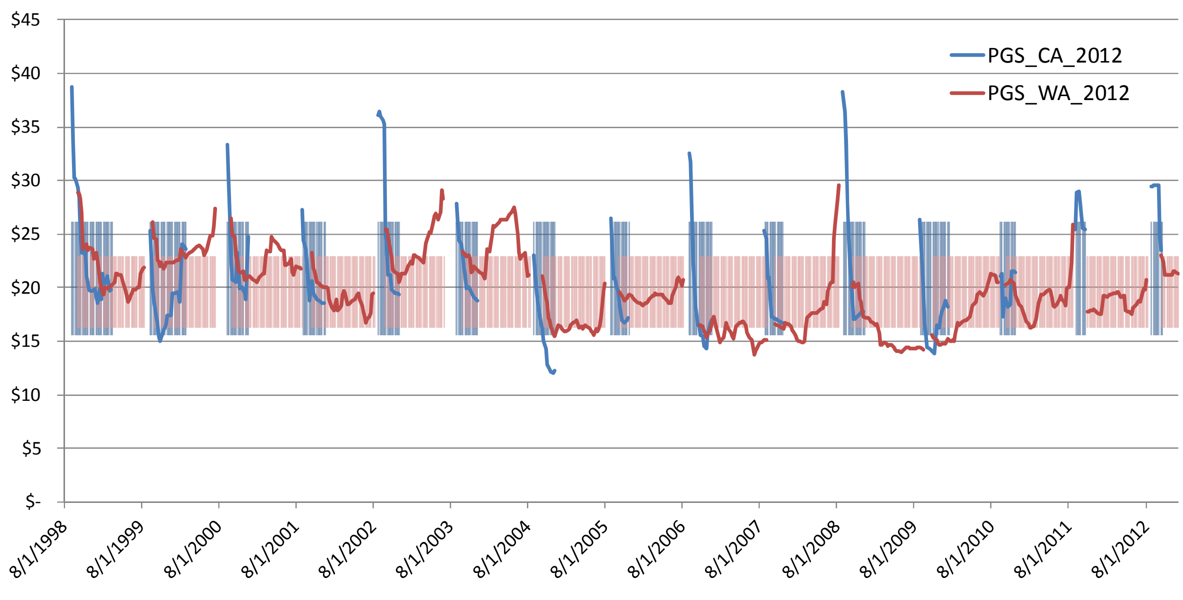
Source: California County Agricultural Commissioners/USDA-NASS

Granny Smith Pricing

Washington State produces approximately 90 percent of U.S. Granny Smiths, which makes the timing of the harvest critical to the marketing of California's crop: California has a limited time period in which to capture premium prices before the onset of the later-season Washington harvest. As shown in **Figure 3** below, California has received a premium price for new-crop Granny Smiths for most of the past 15 years. This premium typically declines rapidly as the new Washington crop approaches.

There is a negative but weak relationship between total crop size and price for Washington and California (as measured by total movement during the crop year): a linear trendline fit for crop size and pricing showed that a one-percent increase in the size of the Washington crop in a given year was associated with a California price decrease of 0.15 percent. The effect of the California crop size was even smaller, with a one-percent increase in crop size associated with a 0.01 percent decrease in price. It is important to note that these are very rough approximations, and a more thorough analysis, taking more factors into account, will be provided by this study.

Figure 3: Weekly Average Domestic Granny Smith Price per Box (2012 Dollars).

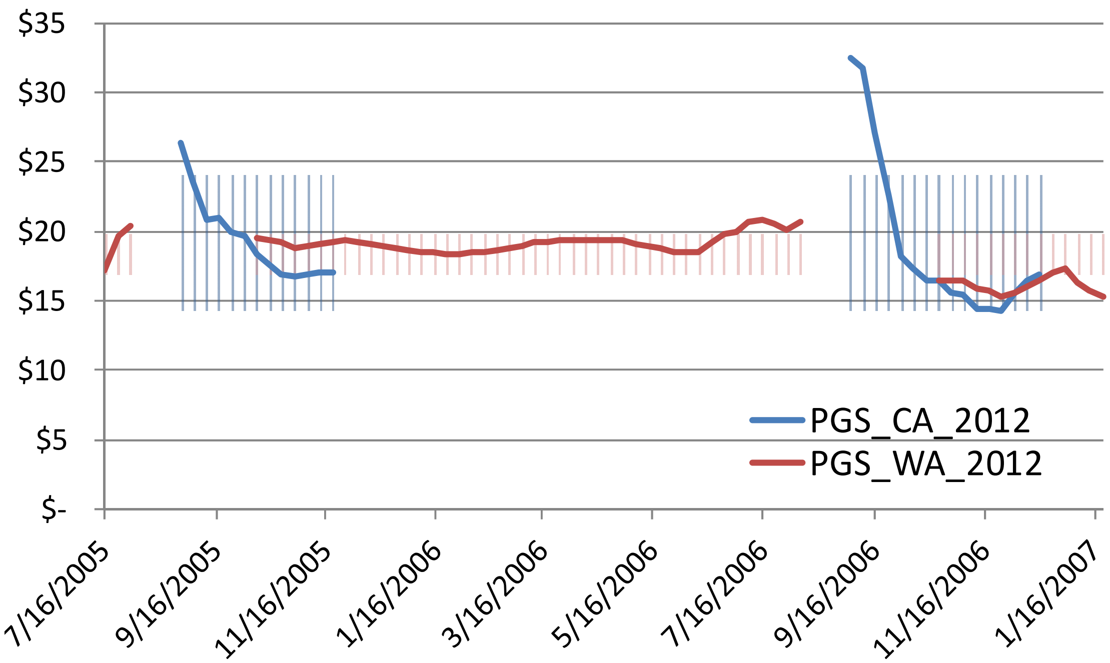


Source: USDA-AMS Fruit and Vegetable Market News

The standard deviation for each price series is shown by the shaded bars – pink for Washington, blue for California.

A closer look at the evolution of Granny Smith Pricing over time (the 2005- and 2006-crop years in this case) illustrates the relationship of California and Washington pricing, as in **Figure 4** below. For the period of time when California was the only supplier of new-crop Granny Smiths, there was often a substantial premium for California over Washington pricing. This premium typically disappeared over a three-to-six-week period, and the California price converged with the Washington price as new-crop Washington apples began to ship. California Granny Smiths typically sold at a discount after Washington entered the market, but in some cases, California pricing improved at the end of its shipping period, as can be seen in the 2005/2006 and 2006/07 crop year pricing in Figure 4.

Figure 4: Weekly Average Domestic Granny Smith Price per Box (2012 Dollars), 2005- and 2006-Crop Years.



Source: USDA-AMS Fruit and Vegetable Market News

Throughout this report, the prices reported are fresh, U.S. Extra Fancy (California) and Washington Extra Fancy grades, size 100s, aggregated on a weekly basis, for 40-pound boxes, covering crop years from 1998/99 to 2012/13. Pricing for organic product was excluded. Data collection methods are detailed in the Appendix.

The Granny Smith Maturity Standard

Origins of the Maturity Standard

In the mid-1990s, members of the California Granny Smith Association enacted a maturity standard for the state's Granny Smith production. This came about due to concerns of some in the industry that immature apples were being marketed, the logic being that these apples were of inferior quality and could negatively impact consumer demand for Granny Smiths that shipped later in the season (CAC 2010).

The maturity standard was based on the results of a testing procedure developed by researchers at University of California, Davis. The standard prohibited the shipping of Granny Smiths from any county until a sample of apples reached a reading of 2.5 on the Starch-Iodine test scale. The standard applied to all Granny Smith apples grown in a county. For example, no Granny Smiths could be shipped from anywhere in Fresno County until an official sampling of apples within the county attained a 2.5 average on the test.

Criticism and Repeal

After its adoption, complaints began to mount from growers and shippers about the idiosyncrasies of the maturity standard. The 2.5 average reading was considered by some to be arbitrary, especially in light of later research showing that many consumers preferred apples with lower SI readings. The release dates were controversial: in some years, northern counties met the standard before southern counties, and there were also reports of fruit being released in one county, while, in a nearby county, fruit was prevented from shipping because the county sample had not met the standard. Finally, some observers believed the standard sent a misleading message that once a county's apples were released, then all the apples in that county were suitable for shipping (CAC 2010).

Responding to industry requests and work by the CAC, CDFA repealed the maturity standard for Granny Smith apples in July 2011.

The issue this study addresses is whether the maturity standard caused unwarranted delays in shipping Granny Smith apples, resulting in lost early-season revenues when prices were highest.

Initial Analysis

In order to estimate the effect of the maturity standard on California Granny Smith shippers, detailed price and shipment data are needed. The approach described below used weekly market data for two reasons. First, annual and monthly-level data do not capture the important timing aspects of the market. A second reason was that daily market data can exhibit a high degree of variation ("statistical noise") that obscures the underlying market dynamics. Daily data are also problematic because they often have missing values that can complicate statistical analyses. Weekly aggregated data were therefore considered to be the most appropriate for this analysis.

Price and shipment data were obtained from USDA-AMS Fruit and Vegetable Market News reports (FVMN) dating back to 1998, the earliest time period for which these data were available. FVMN captures data on 100 percent of Washington apple shipments and approximately 95 percent of California statistics, and as such are considered a reliable indicator of the apple market for these states.

ANOVA

The initial look at the data used an analysis of variance (ANOVA) procedure. This is typically the first step in an econometric analysis, and was used here to obtain an estimate of the effect of the maturity standard on market pricing. The ANOVA grouped California Granny Smith prices into two sub-samples – years with the maturity standard (1998-2010) and years without the standard (2011-2012) – and identified whether these sub-sample means were equal. All prices are reported in real (2005) dollars.

The results of this ANOVA showed that when the maturity standard was in effect, California Granny Smith prices averaged approximately $17.55 per box. In the two years since the maturity standard was repealed, the California Granny Smith price was over $10 higher per box than when the maturity standard was in effect. The relevant statistics are shown in bold text in **Table 2** below.

In a counterintuitive result, the coefficient of variation (CV) of the ANOVA indicates pricing in the post-maturity standard period was less volatile, meaning that Granny Smith pricing was both higher and more stable after the maturity standard was repealed. Typically, one would expect a higher CV in a smaller data set (the two years after the repeal of the standard). It remains to be seen whether these results will hold in future crop years.

Table 2: ANOVA: California Granny Smith Price per Box, During/After Maturity Standard, 1998-2012.

	Sum of squares	df	Mean square	
Treatment	1491.33	1	1491.33	
Residual	3914.09	230	17.0178	
Total	5405.42	231	23.4001	
F(1, 230) = 1491.33 / 17.0178 = **7.6334*** F_{CRIT}(1, 230) at α = 0.05 = **3.8822**				
Level	# observations	**mean**	std. dev	**CV**
0 (After maturity std.)	15	**27.8405**	2.0918	**0.0751**
1 (During maturity std.)	217	**17.5531**	4.1717	**0.2377**

Notes: Grand mean = 20.944, *-significant at α = 0.05 level.

Since pricing for all apples in 2011 and 2012 was notably higher than in previous years, a second ANOVA was run, comparing the differential between the California and Washington Granny Smith prices and the average price of all apples. This is reported in **Tables 3 and 4 below**. Note that, while California Granny Smith pricing improved notably (over $3 per box) after the repeal of the maturity standard, no such effect was found in Washington pricing. This could imply that the change in policy was indeed a driver for increased revenues for California suppliers.

Table 3: ANOVA: Price Differential for California Granny Smiths vs. All-Apple Price per Box, During/After Maturity Standard, 1998-2012.

	Sum of squares	df	Mean square	
Treatment	148.69	1	148.69	
Residual	2035.53	230	8.85012	
Total	2184.22	231	9.45549	
F(1, 230) = 148.69 / 8.85012 = **16.8009*** F_{CRIT}(1, 230) at α = 0.05 = **3.8822**				
Level	# observations	**mean**	std. dev	
0 (After maturity std.)	15	**3.0384**	2.2154	
1 (During maturity std.)	217	**-0.2171**	3.0176	

Grand mean = -0.00658. *-significant at α = 0.05 level.

Table 4: ANOVA: Price Differential for Washington Granny Smiths vs. All-Apple Price per Box, During/After Maturity Standard, 1998-2012.

	Sum of squares	df	Mean square	
Treatment	32.0653	1	32.0653	
Residual	2044.52	634	3.22479	
Total	2076.58	635	3.27021	
$F(1, 634) = 32.0653 / 3.22479 =$ **9.94335*** $F_{CRIT}(1, 634)$ at $\alpha = 0.05 =$ **3.8562**				
Level	# observations	**mean**	std. dev	
0 (After maturity std.)	53	**-0.49536**	1.5543	
1 (During maturity std.)	583	**0.31705**	1.8158	

Grand mean = 0.24935. *-significant at α = 0.05 level.

Another way of looking at the issue is to consider the price obtained when California is the only new crop supplier in the marketplace. In this case, California Granny Smith shippers received $22.40 per box in the period between the start of the California shipping season and the start of the Washington crop, compared to $15.90 per box after Washington product began shipping. The relevant statistics are shown in bold in **Table 5** below.

Table 5: ANOVA: California Granny Smith Price per Box When CA is Sole Supplier of New Crop, 1998-2012.

	Sum of squares	df	Mean square	
Treatment	2240.57	1	2240.57	
Residual	3164.85	230	13.7602	
Total	5405.42	231	23.4001	
$F(1, 235) = 2240.57 / 13.7602 =$ **162.83*** $F_{CRIT}(1, 230)$ at $\alpha = 0.05 =$ **3.8822**				
Level	n	**mean**	std. dev	**CV**
0 (CA+WA supply)	155	**15.9932**	2.1362	**0.1336**
1 (CA only supply)	82	**22.4003**	5.5598	**0.2482**

Grand mean = 18.1971. *-significant at α = 0.05 level.

These initial results suggested that the maturity standard had a negative effect on California pricing during the years analyzed. In order to arrive at a more accurate figure, a more detailed economic model has been developed, and will be described in the next section.

Economic Model of the Granny Smith Maturity Standard

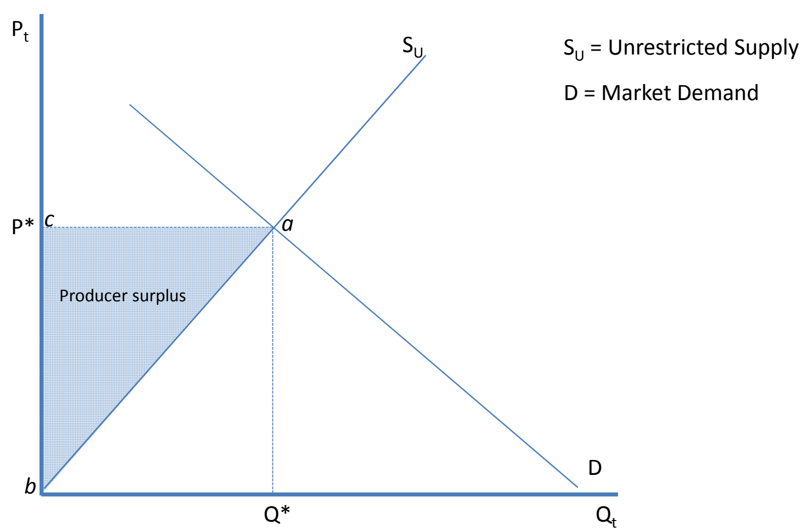
Conceptual Overview

As mentioned previously, Granny Smith pricing exhibits a strong seasonal pattern as first California and then Washington State enter the harvest season over the course of the year. The timing of the Granny Smith harvest is critical to the marketing of California's crop: suppliers have a limited time period in which to capture premium prices prior to the onset of the later-season Washington crop.

In an unrestricted market, California shippers are free to move product at any time according to market conditions and fruit quality; however, with a maturity standard in effect, movement of otherwise marketable fruit may have been artificially delayed. These two possibilities are illustrated below.

Without the maturity standard, the Granny Smith market can be represented, in the short-run, with a downward-sloping demand curve and an upward-sloping, supply curve, as in **Figure 5**. The fresh market is assumed to clear at point "*a*" on the graph, at price P* and quantity Q*. Producer surplus, the benefit producers receive above their marginal production costs (*i.e*, the supply curve), is shown by the shaded area, below.

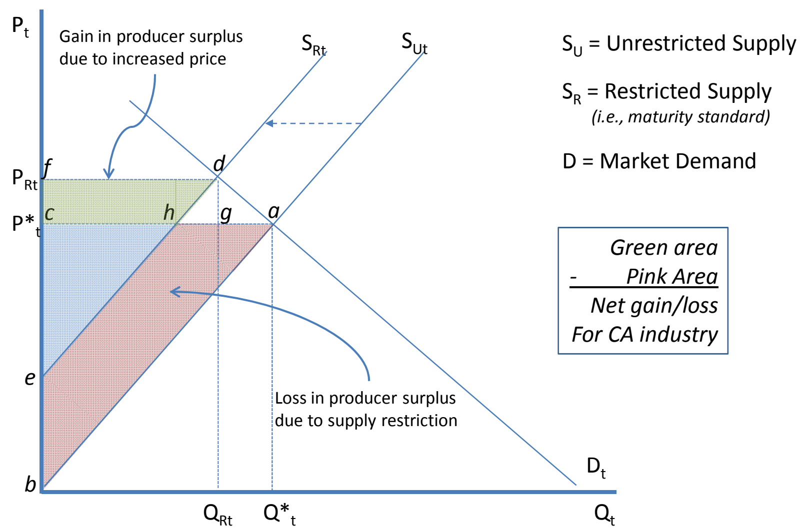
Figure 5: Unrestricted Granny Smith Market



If Granny Smith shipments are delayed due to a maturity standard, there will be a temporary drop in California supply, as localized California shippers are prevented from entering the market. This is reflected in the leftward shift of the supply curve, from S_U to S_R, as illustrated in **Figure 6** below. The expected effect is an increase in market price to P_R and a decrease in quantity sold to Q_R due to the supply restriction.

The change in producer surplus due to the decrease in quantity supplied is given by the area of the red-shaded region in the chart, denoted by the polygon *abeh*. The change in producer surplus due to the increased price caused by the restriction is shown in the green-shaded area, denoted by polygon *dhcf*. If *abeh* is larger than *dhcf*, then the maturity standard would have a negative impact on California industry revenues. This would occur if the price elasticity of Granny Smiths is relatively large (e.g., a one percent increase in price results in greater than one percent decrease in quantity demanded). A review of the literature on price elasticities suggests that this is indeed the case, so one would expect the maturity standard to negatively impact California Granny Smith producer welfare.

Figure 6: Restricted Market Due to Maturity Standard



Once the maturity standard has been met, the market reverts to the unrestricted case shown in Figure 5; however, the initial delay will cause California marketers subsequently either to sell the same amount of apples over a shorter time period, or sell product later in the season, when supplies from competing regions are more abundant. In either case, prices realized after the maturity standard has been met would likely respond somewhat negatively.

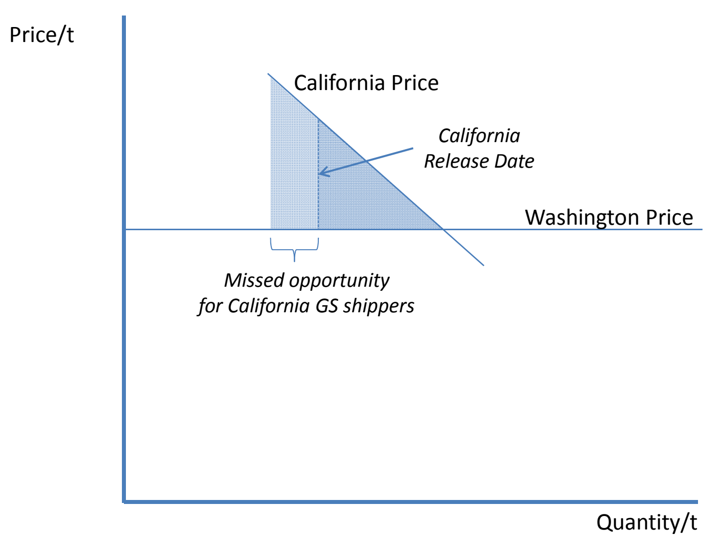
While the producer surplus concept (*i.e.*, P>Marginal Cost) described above would require data on grower production costs in order to estimate a supply function (the summation of grower incremental/marginal costs), the data that were available for this study do not allow for such an estimate, and so the benefit-cost framework is not used here. Rather, the economic impact will be conservatively defined as the net present value (NPV) of the revenues foregone or gained as a result of the maturity standard (as in Table ES1).

Price dynamics: California vs. Washington

As the above conceptual model implies, a key focus of this analysis is the evolution of California Granny Smith pricing over time. **Figure 7**, below, shows a generalized relationship between California's Granny Smith release date and market pricing, Over the 15-year history for which data are available, California prices were consistently highest at the beginning of the shipping period in each crop year. By the time Washington began shipping, the California price converged with the Washington price, after which fruit often sold at a discount. These two facts are consistent with the assumptions in the conceptual model.

Therefore, a price model must be developed that is capable of estimating what California Granny Smith pricing *would have been*, if there had been no maturity standard and suppliers were free to ship product earlier. This price model will then be coupled with estimates of shipment volume over this time period to arrive at an estimate of revenues that were foregone due to the maturity standard.

Figure 7: Price behavior of California Granny Smiths with maturity standard



Note that, if California represents a large enough portion of the supply in the early shipping period, it will affect the price as well, and the model should account for this.

Additional questions arise when taking the long run into account. For example, if Granny Smith growers were negatively impacted by the maturity standard in the early years of its use, they may have been induced to take Granny Smith acreage out of production in favor of other varieties, or, alternatively, exit the market. This would affect subsequent pricing, production volume, and profitability of other California-grown varieties. The focus of this study is specifically on the annual incidence of the maturity standard, and these long-run effects are not addressed by this model.

Literature Review

Economic impacts of commodity promotion programs

Economic evaluation of commodity commission activities often centers on the efficacy of generic promotion and advertising programs. Many of these evaluations are carried out in compliance with federal commodity research and promotion (i.e., "checkoff") programs that are funded through industry assessments. There are currently 19 federal checkoff programs ranging from beef cattle, dairy, and eggs to multiple crops and even softwood lumber (USDA-AMS 2009). The program authorities (e.g., the U.S. Highbush Blueberry Council) must periodically evaluate the economic impacts of these promotions (7 U.S.C. 7411-7425, Sec 515(h)), and the resulting literature was the first source of review for the present project.

It is important to note that the California Granny Smith maturity standard was specific to California shippers of fresh Granny Smiths. Administration of the standard was associated with state commodity commission law; however, the closest source of economic literature on the topic was found to be related to federal programs.

A common characteristic of the economic evaluation of these programs is their use of a benefit-cost framework, in which producer benefits are compared with program costs. Since the present study does not evaluate the existence of the Granny Smith maturity standard as a commodity "program," this approach is not used here; however, key elements of the economic modeling approach were adapted from these studies, most notably an evaluation of the U.S. Highbush Blueberry Council by Kaiser (2010), a paper on dynamic changes in producer surplus by Hossain and Maxwell (1986), and an extensive study of the California Table Grape Commission by Alston, et al. (1997). These include the choice of partial, rather than general equilibrium analysis, and the econometric methods for estimation of model parameters.

Market windows and hedonic price analysis

The temporal aspect of the Granny Smith standard is essential to uncovering its economic impact on the California industry. The period in which California is the only supplier of new crop apples might be thought of as a "market window," Two strains of market window analysis were reviewed. The first, dating at least as far back as the 1970s, was developed to help farmers identify the most profitable time to market their fresh produce. Tronstad, Huthoefer, and Monke (1992) merge this approach with hedonic price analysis in the U.S. apple industry, examining the role of product quality characteristics in apple pricing. These methods are used to demonstrate the role of product quality on price during such market windows. Additional background on hedonic price analysis in the apple industry was provided by Carew (2000), McCluskey, et al. (2007), and Wang and Ge (2006), and guided the econometric approach.

Impact of minimum quality standards

The Granny Smith maturity standard might be thought of as a minimum quality standard (MQS) that holds over a period of time. Saitone and Sexton (2010) introduce a model examining the effects of such standards in marketing orders and find that, in general, an MQS reduces social welfare in two ways: first, by an inefficient enhancement of product quality, and second, by the wastage of low-quality product that cannot be marketed due to the standard. This differs slightly from the California Granny Smith case, as all product (in principle) could still be marketed once the maturity standard was met; however, it does suggest the possibility of a loss of social welfare while such a standard is in place.

Technical barriers to trade

A second way of looking at the Granny Smith maturity standard is as a technical barrier to trade. This approach models the regulatory control of supply as a backward shift of the supply curve, and analyzes the effect of the regulation on producer and consumer surplus. This approach was used by Richards, Molina, and Hussein (2009) in an analysis of a quarantine on U.S. potatoes in Mexico, which found that import restrictions reduced consumer and producer welfare.

Demand elasticities of fresh fruit

Various estimates of demand elasticities of fresh fruit have been published over the years. Two papers referenced here, Price and Mittelhammer (1979) and Durham and Eales (2006) arrive at estimates that suggest a limited amount of substitution between apples and other fruit: In Durham and Eales, for example, the largest cross-price elasticity estimate for apples is with grapes at 0.18. This suggests a relatively low cross price or inelastic response between the prices of apples and other substitutes.

Methods and Data

Based on the literature review, the nature of the analysis, and the availability of data, two equations were used to model the quantity and price of California Granny Smiths over the study period. The quantity model (QGS) was used to estimate the weekly movement of California Granny Smiths into retail channels over time, allowing the effects of the maturity standard on weekly quantities to be isolated. The price model (PGS) used the output of the QGS model to estimate price as a function of the available supply of Granny Smiths, substitute goods (*i.e.*, other fresh fruit), and other variables.

The key variables considered for the model include the following:

- Price of Granny Smiths by state (Source: USDA)
- Prices of all other varieties by state (Source: USDA)
- Movement by origin and (for some years) by variety (Source: USDA)
- Imports and exports (Source: U.S. International Trade Commission)
- U.S. apple holdings by variety (Source: U.S. Apple Association)
- Per capita disposable income (Source: U.S. Bureau of Economic Analysis)
- Per capita availability of fresh fruit other than apples (Source: USDA-ERS)
- A variable to distinguish when the Granny Smith maturity standard was in effect (Source: California Apple Commission)
- Variables to measure the number of days since the initial harvest of each year's crop (a proxy for product quality)
- A variable to distinguish weeks during which California was the sole supplier of new-crop apples

As will be explained in the results section, some of the above variables did not significantly explain changes in price and quantity and were excluded from the final models.

Estimating the Quantity of Granny Smiths (the QGS Model)

As the prices received by shippers of Granny Smiths are treated as a function of movement of product from packers into retail channels (*i.e.*, the leftward shift in the supply curve as illustrated in Figure 6 on page 16), these data are critical to the construction of the forecasting model.

Only six years of California Granny Smith movement data are available (2005/06 through 2010/11 seasons), so the quantity of Granny Smiths entering the market were estimated for the missing movement data periods. Ordinary least squares

(OLS) regression was used to estimate missing values for the 1998/99 through 2004/05 and 2011/12 through 2012/13 crop years.

Since Granny Smiths comprise such a relatively large proportion of California apple shipments (from 40 percent to over 50 percent, depending on the year), a starting assumption is that the distribution of California apple shipments over time was dominated by Granny Smiths. Following from this assumption, the movement of California Granny Smiths during the years with a maturity standard can be regarded as a function of all California apple shipments and the county release dates.

The general form of the QGS model is depicted in the following equation:

$$QGS_t = \theta_i(\beta_0 + \beta_1 Movement\_CA_t + \beta_3 Restrictions_t + \beta_4 DCropYear_t) \qquad (1)$$

Where β are the unknown parameters on each of the predictive variables , β_0 is a constant, and θ_i is a factor that scales the output of the equation so that the sum of QGS over all time periods equals the total (known) domestic shipments of California Granny Smiths in a given crop year. Total actual shipments are taken from the California Apple Commission's annual reports.

The dependent variable, *QGS*, is the weekly quantity of California Granny Smiths moving into domestic retail channels. While California does export between 10% and 20% of its Granny Smiths, imports and exports are not included, largely because weekly statistics are not readily available by variety for imports, while they are available for six years of domestic movement.

Movement_CA represents the movement of all California apples into domestic retail channels. Unlike *Movement_CA_GS*, these data are available for all years considered in this study.

Restrictions are dummy variables for apple-shipping counties that take the value 1 if that county has met the maturity standard for Granny Smiths and zero otherwise. San Joaquin and Santa Cruz counties were the only two that had a statistically significant effect on Granny Smith movement, and were the only ones used in the model.

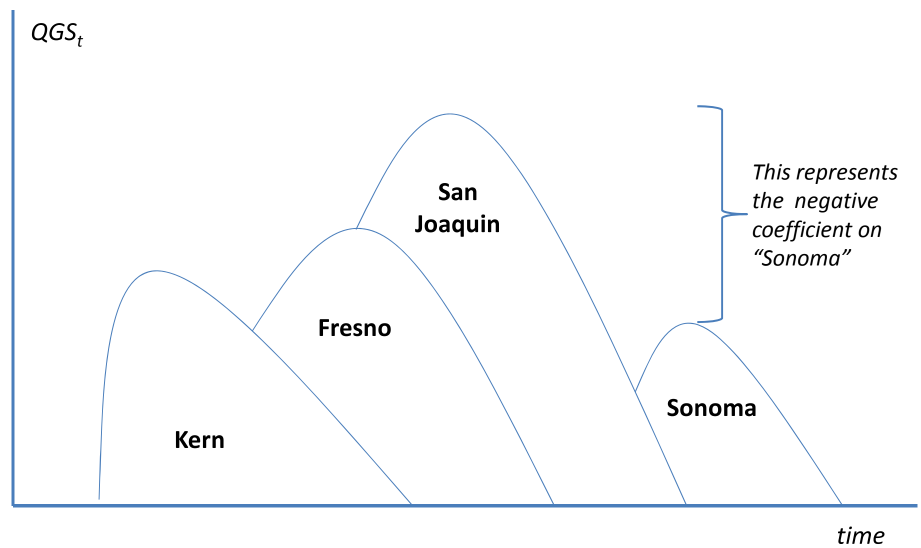
*DcropYear_* is a dummy variable denoting the crop year in which Granny Smith movement was observed. For example, California Granny Smith prices were recorded from September through December 1998. These are classified in the 1998-crop year. These variables are used to account for unobserved factors that may influence the timing of movement, such as weather conditions during crop development, cultural practices, and the movement of other apple varieties. Dummy variables for the 2005/06 through 2009/10 season were included in the model, while 2010/11 was excluded to avoid collinearity.

Three model variants were estimated using Ordinary Least Squares (OLS) and appear in the Appendix. The model chosen for further analysis (QGS3) was then used to estimate the weekly movement of Granny Smiths if the maturity standard did not apply. This resulted in two data series for movement: the *actual* movement (with the maturity standard intact) and the "unrestricted" movement.

For the six years in which Granny Smith movement data are available, QGS3 fits the data with an adjusted R-squared value of 0.89, meaning the model can explain 89 percent of the variation in prices over the six-year period.

One note on interpreting the coefficients of the model is necessary. When the coefficients on the county release date are negative (Sonoma, in this case), this does not imply that *movement from that county* is negative; rather, it is the marginal change in *movement for the entire market* at that point in time. As illustrated in **Figure 8** below, Sonoma County was typically released well after statewide Granny Smith shipments had peaked:

Figure 8: Interpreting the Negative Coefficient in the QGS Model.



Results of the OLS regression for the QGS 2 model are shown in **Table 6**, below.

Table 6: QGS3: OLS, using observations 1998-08-01:2012-12-29 (T = 149)
Missing or incomplete observations dropped: 604
Dependent variable: Movement_CA_GS

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	-262.282	31.9428	-8.2110	<0.00001	***
Movement_CA	0.507192	0.0258597	19.6133	<0.00001	***
San_Joaq	323.468	24.5127	13.1959	<0.00001	***
Sta_Cruz	-84.6795	20.6199	-4.1067	0.00007	***
DCropYear_9	59.9376	18.1174	3.3083	0.00119	***
DCropYear_10	85.5483	17.2726	4.9528	<0.00001	***
DCropYear_11	40.9442	19.8024	2.0676	0.04052	**
DCropYear_12	56.0655	16.639	3.3695	0.00097	***
DCropYear_13	36.9634	18.2671	2.0235	0.04492	**

Mean dependent var	219.6443	S.D. dependent var	193.1735
Sum squared resid	552968.6	S.E. of regression	62.84724
R-squared	0.899875	Adjusted R-squared	0.894153
F(8, 140)	157.2811	P-value(F)	4.97e-66
Log-likelihood	-823.7456	Akaike criterion	1665.491
Schwarz criterion	1692.527	Hannan-Quinn	1676.475

Estimating the Price of Granny Smiths (the PGS Model)

The Granny Smith pricing model is based on variables describing the supply of apples at a given week *t*. The PQS model is depicted in the following equation:

$$PGS_t = \rho_0 + \rho_1 GS\ Stocks_t + \rho_2 QGS_t \quad + \rho_2 DCropYear_t + \rho_3 P\_All_t + \rho_4 CA\_Only\_GS_t \qquad (2)$$

Where ρ are the unknown parameters on each of the predictive variables and ρ_0 is a constant.

The dependent variable, *PGS*, is the average real weekly price per 40-lb carton of California Granny Smith apples (in 2012 dollars). These are reported for the 1998 to 2012 crop years.

The independent variables include the following:

GS_Stocks represents the weekly holdings of Granny Smiths in the U.S, in millions of pounds. This term is expected to be negatively related to price, as higher inventories imply a higher level of supply relative to demand, or conversely, a lower rate of disappearance, which indicates lower demand. A one-week lag of *GS_Stocks* was tested but did not improve the explanatory power of the model.

QGS is the movement of California Granny Smiths at week *t*, taken from the fitted values of the QGS model described in the previous section.

*DcropYear_* is a dummy variable denoting the crop year in which Granny Smith prices were observed. In this case, it is used to account for unobserved variables that may have impacted pricing. These could include the market concentration of shippers and wholesale buyers, promotional efforts by industry organizations, favorable or unfavorable events reported in the news media, and changes in consumer preferences.

P_All is the average price of all Washington and California apples in week *t*. This was included to account for changes in the price level, which was expected to influence the price of all apple varieties. It was also included to avoid large over- and under-estimation of prices when the hypothetical, "unrestricted" prices were estimated.

CA_Only_GS represents the period during which California is the sole supplier of new-crop Granny Smiths in the market. This coefficient is expected to be positive, as it represents the period of time in which California Granny Smith shippers have the greatest market power, and may also be a proxy for product quality, as California is the only source of new-crop apples at this time (less than six months vintage).

Some of the variables for available market supply, such as net exports and the availability of substitutes were tested; however, none were significant, and their inclusion did not improve the results. A key reason for this is that a large number of observations needed to be dropped because of missing data points.

The PGS3 model is summarized in **Table 7**, below.

Table 7: PGS3: OLS, using observations 1998-08-01:2012-12-29 (T = 206)

Missing or incomplete observations dropped: 547
Dependent variable: PGS_CA_2012

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	12.3368	1.76668	6.9831	<0.00001	***
GS_Stocks	-0.037244	0.00199307	-18.6867	<0.00001	***
CA_Only_GS	1.8271	0.375048	4.8717	<0.00001	***
DCropYear_2	3.34091	0.590181	5.6608	<0.00001	***
DCropYear_3	-5.28267	0.519398	-10.1708	<0.00001	***
DCropYear_8	-1.39017	0.58633	-2.3710	0.01872	**
DCropYear_9	3.42047	0.652764	5.2400	<0.00001	***
DCropYear_12	3.19059	0.774266	4.1208	0.00006	***
P_All_Deflated	1.25522	0.0949735	13.2165	<0.00001	***
QGS	4.06724e-06	3.65638e-06	1.1124	0.26736	

Mean dependent var	20.51653	S.D. dependent var	5.262486
Sum squared resid	788.5180	S.E. of regression	2.016067
R-squared	0.859740	Adjusted R-squared	0.853233
F(9, 194)	132.1274	P-value(F)	8.88e-78
Log-likelihood	-427.3711	Akaike criterion	874.7421
Schwarz criterion	907.9233	Hannan-Quinn	888.1645

Results and Discussion

Using the QGS and PGS models, price and movement estimates were made for the periods when California Granny Smiths *could have shipped had there been no maturity standard.* **Model results show that, from 1998 to 2010, the California Granny Smith maturity standard could have delayed the start of shipments by up to 5 weeks in some years.** Graphical results of this effect can be found in Figures 9 (A-E) below.

The Weekly GS Movement charts show the estimated movement of Granny Smiths with the maturity standard in place (in blue) and an alternate scenario in which Granny Smith movement was not restricted by the standard (in green). As can be seen, additional early-season movement was seen in the alternate scenario. This effect ranged in size, and was barely noticeable in one season (2000/01).

Similarly, the Weekly GS Price charts show the actual Granny Smith Price in blue, with the alternate scenario prices from the PGS model in red. In general, the early-season premium is slightly lower with the maturity standard removed, which suggests that the overall revenue increases were driven by the additional movement early in the season.

Figure 9A: Estimated Weekly GS Movement and Pricing: With and Without Maturity Standard

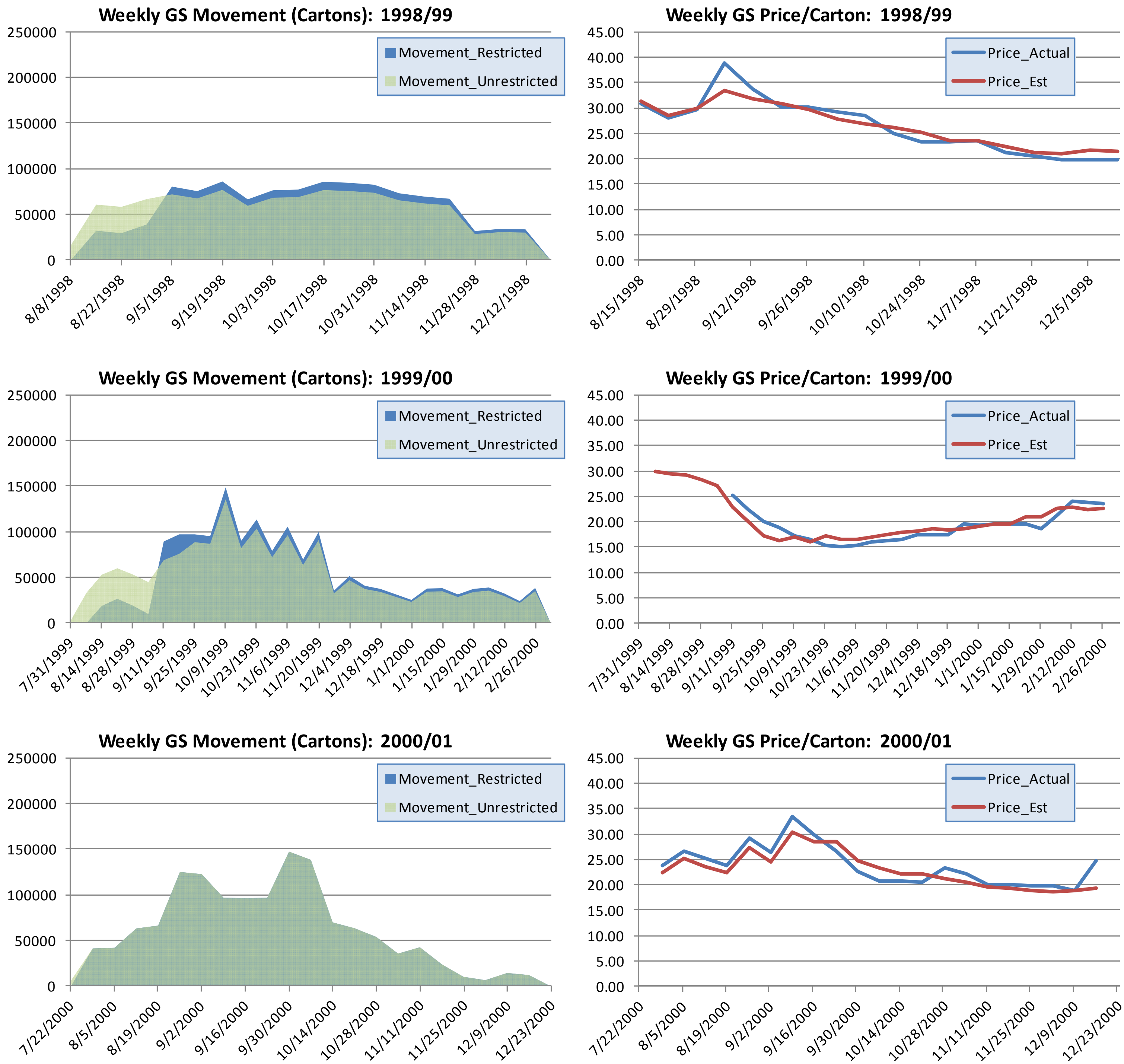


Figure 9B: Estimated Weekly GS Movement and Pricing: With and Without Maturity Standard

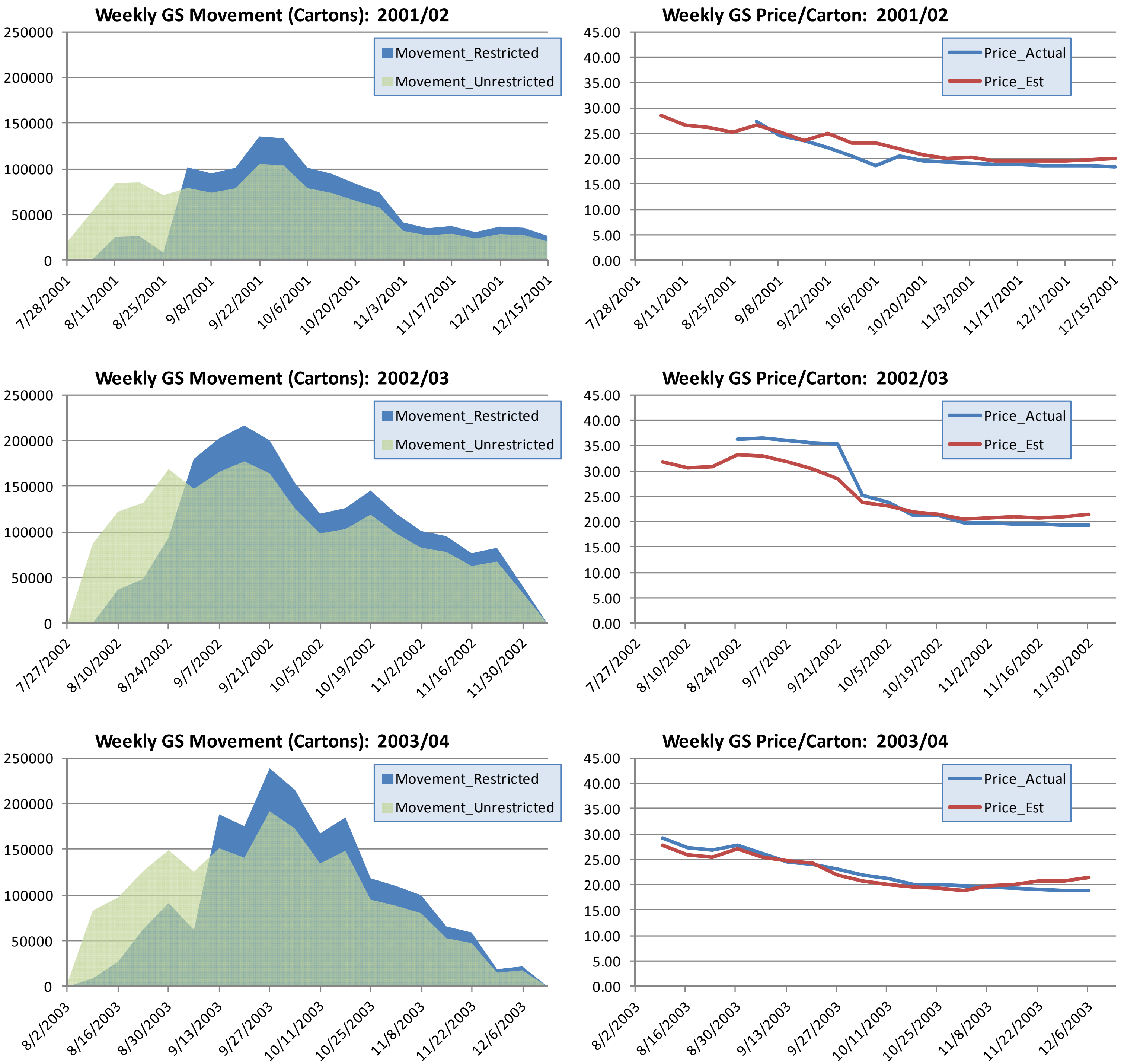


Figure 9C: Estimated Weekly GS Movement and Pricing: With and Without Maturity Standard

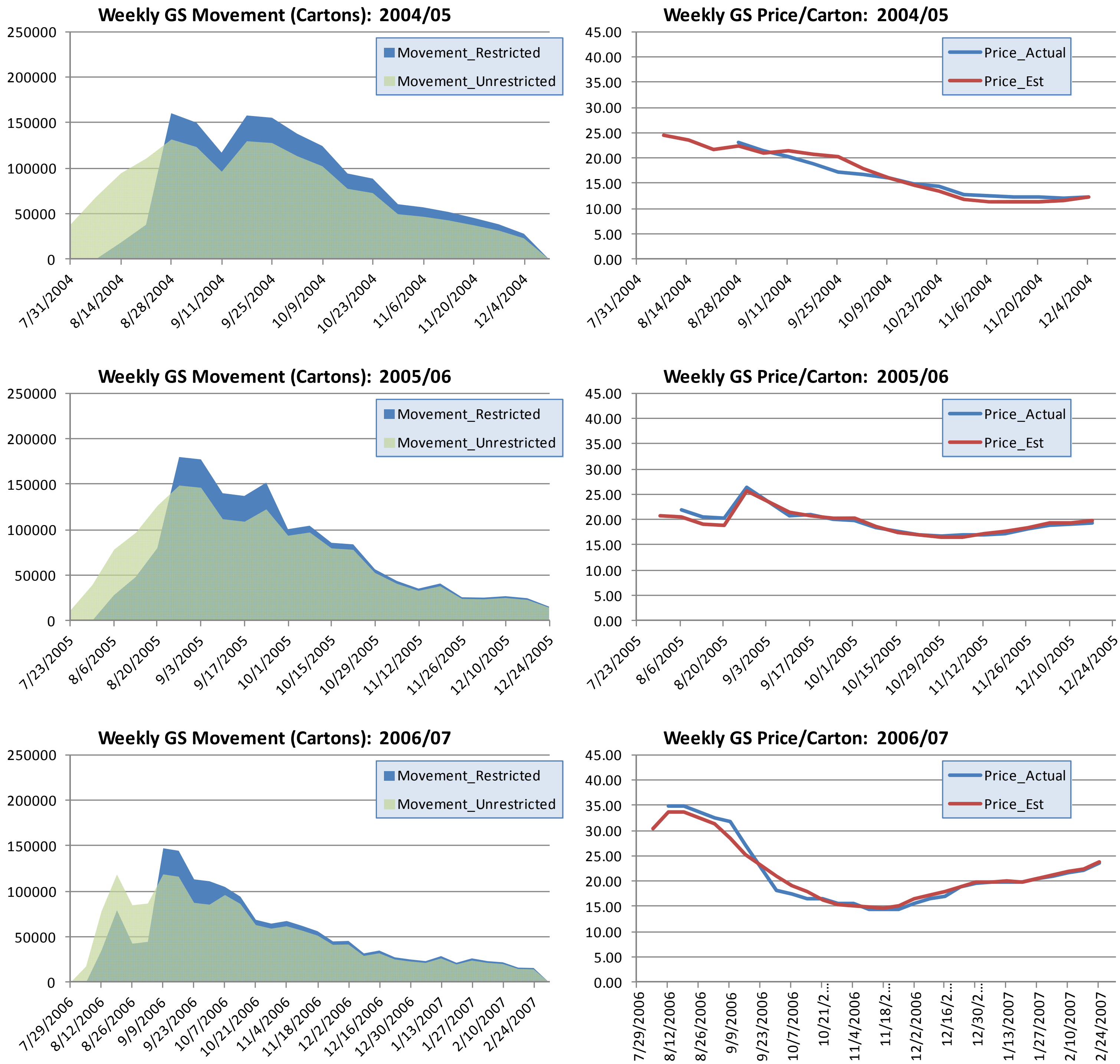


Figure 9D: Estimated Weekly GS Movement and Pricing: With and Without Maturity Standard

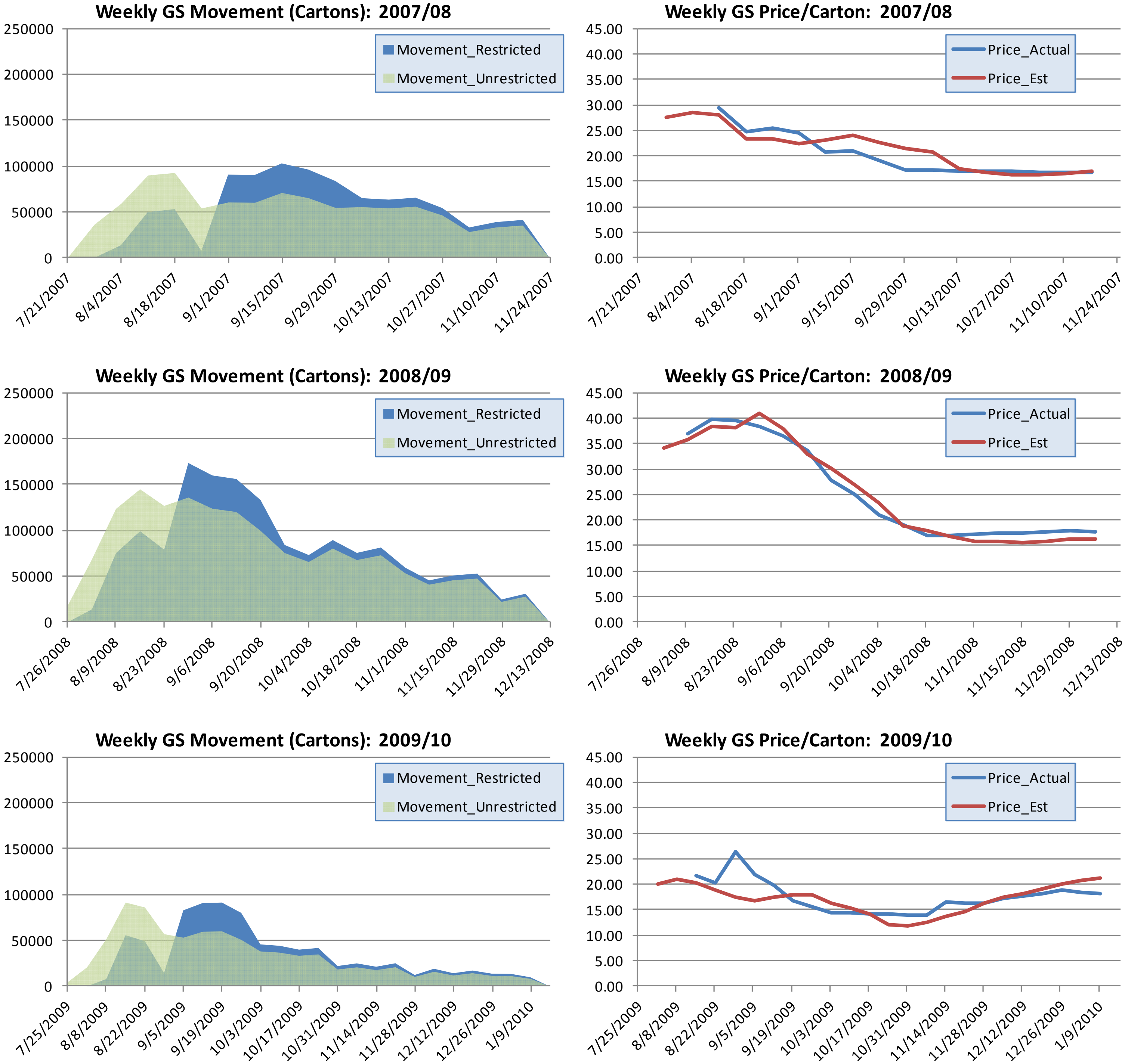
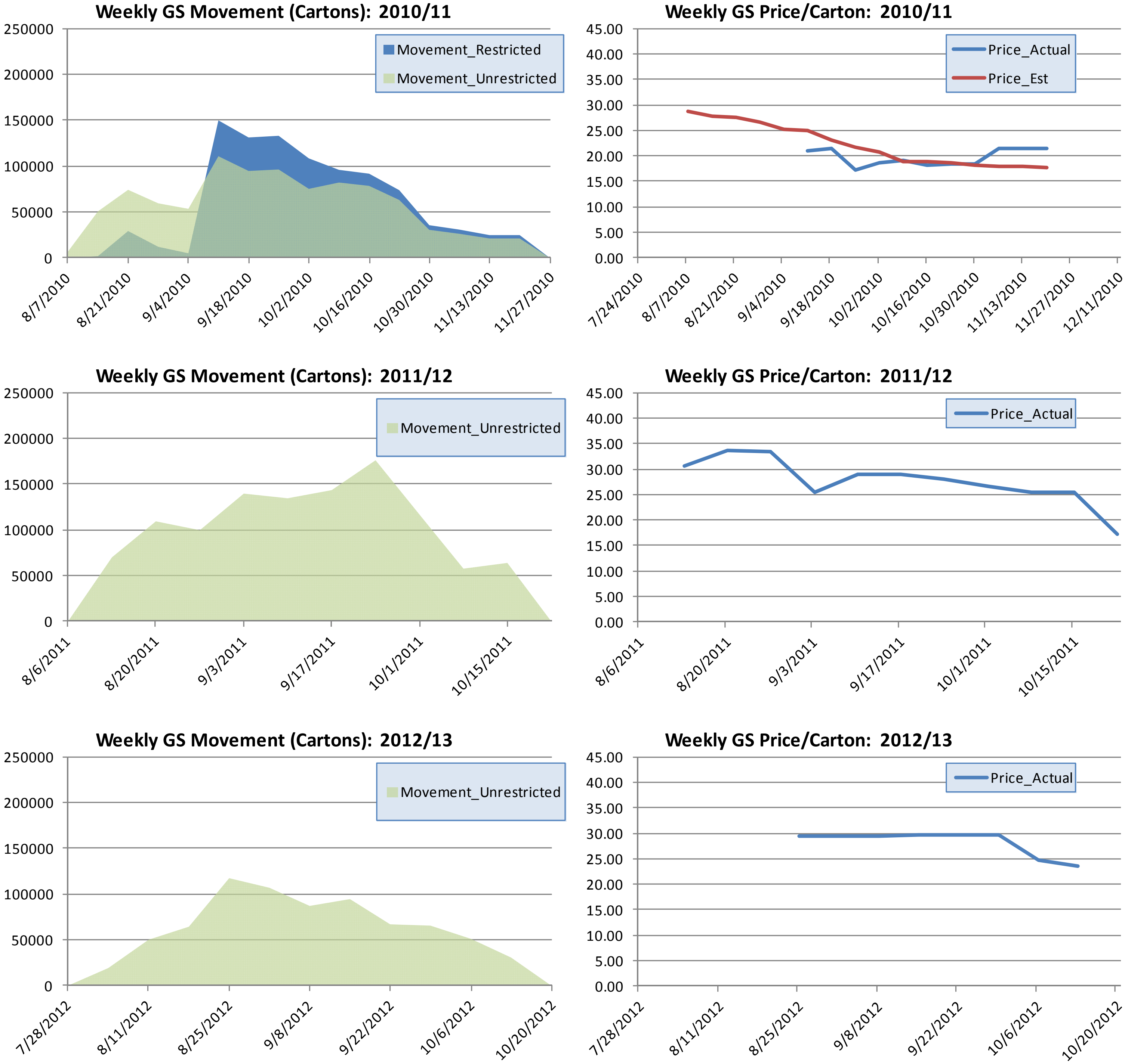


Figure 9E: Estimated Weekly GS Movement and Pricing: With and Without Maturity Standard



Results of the econometric model indicate that, for nine of 13 crop years, Granny Smith sellers would have obtained additional revenues in the absence of a maturity standard.

The results from the pricing model developed in this study suggest that the early-season premium obtained by California shippers would have been maintained in the absence of the maturity standard. Higher revenues would have been obtained due to a longer shipping period and an overall higher price level for Granny Smiths over the duration of the season.

Model results show that, from 1998 to 2010, the California Granny Smith maturity standard could have delayed the start of shipments by up to five weeks in some years.

By prohibiting the shipment of *any* Granny Smiths from a county until the maturity standard was met, marketable fruit was likely kept out of the market. While this is an intuitive finding, without explicit data it is difficult to estimate the likely effect of the standard on shipment patterns, pricing, and revenues. This study appears to be the first to attempt to estimate the magnitude of the effect.

The effect of the Granny Smith maturity standard on California industry revenues is estimated at a negative $18.7 million over the 13 years for which data were available.

The maturity standard is estimated to have reduced industry revenues in nine of 13 years and increased revenues in four years.

With over 18.4 million boxes of Granny Smiths shipped between the 1998 and 2010 seasons, this figure corresponds to a loss of approximately $1.01 per box on average over the 13-year period.

Table 8 presents the difference in revenues for California Granny Smiths in the actual vs. alternate scenarios in 2012 dollars.

Table 8: California Granny Smith Revenues vs. Alternate Scenario, 1998-2012.

Crop Year	Actual Revenue	Estimated Revenue w/o Maturity Std	Effect of Maturity Standard	Actual Boxes	Effect/Box
1998/99	$29,965,469	$29,678,339	$741,702	1,116,498	$0.26
1999/00	$29,379,099	$32,926,950	($3,447,322)	1,661,708	($2.14)
2000/01	$34,137,052	$33,554,262	($124,296)	1,373,057	$0.42
2001/02	$24,683,113	$28,453,905	($3,583,155)	1,226,123	($3.08)
2002/03	$54,566,273	$55,338,107	($738,573)	2,038,501	($0.38)
2003/04	$42,819,834	$43,546,009	($1,428,568)	1,917,234	($0.38)
2004/05	$25,387,337	$27,455,642	($2,478,267)	1,522,188	($1.36)
2005/06	$32,664,615	$32,011,003	$267,985	1,651,577	$0.40
2006/07	$35,345,227	$37,155,636	($2,160,492)	1,617,379	($1.12)
2007/08	$18,539,934	$20,953,566	($2,756,873)	944,772	($2.55)
2008/09	$43,732,151	$45,368,763	($2,232,801)	1,552,127	($1.05)
2009/10	$14,651,029	$14,552,716	($241,227)	839,175	$0.12
2010/11	$17,502,093	$21,059,789	($3,485,658)	948,167	($3.75)
2011/12	$31,875,906			1,113,778	
2012/13	$27,674,770			751,244	
Total	**403,373,226**	**422,054,688**	**($18,681,462)**	**18,408,506**	**($1.01)**

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Appendix

1. Detailed Data Collection Methods

Price and movement data were obtained from the USDA-Agricultural Marketing Service's Fruit and Vegetable Market News Portal (http://www.marketnews.usda.gov/portal/fv). The following two reports were used:

- Shipping Point Reports – By Commodity (State)
- Movement Reports – By Commodity (State)

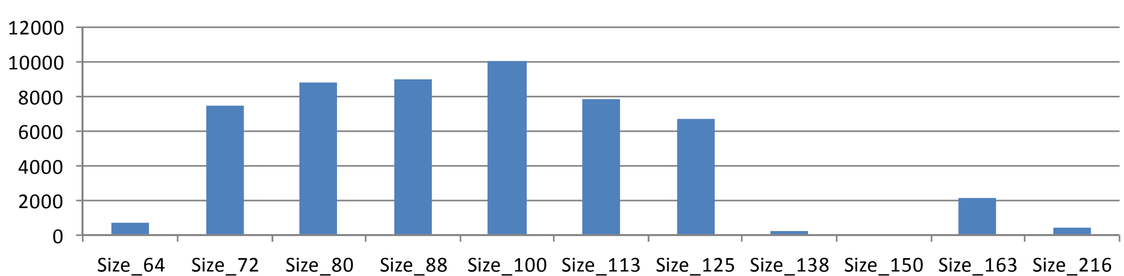
Both reports were run for weekly aggregated data for apples from the top six producing states: Washington, New York, Michigan, Pennsylvania, California, and Oregon. These six states have accounted for approximately 90 percent of all U.S. fresh apple production since 1994.

After running these reports and reviewing industry data as reported by the U.S. Apple Association and USDA-NASS, it became clear that Granny Smith production in states other than California and Washington was minimal, with no shipping point data reported for New York, Michigan, and Oregon. Prices were reported for Pennsylvania; however, as they were all reported in the December-March time period, and knowing that so little of the U.S. Granny Smith supply is grown outside California and Washington, these data were omitted (see Table 1, page 6).

As a result of the above findings, the other states were dropped from the analysis, leaving only Washington and California.

Prices for size = 100s were used in the analysis, as there were more observations for this size than for any other, as shown in **Figure A1**, below.

Figure A1: Distribution of Granny Smith Price Observations by Size, 1998-2012.



2. Technical Notes

Table A1: Summary Statistics of Model Variables

Variable	Mean	Median	Minimum	Maximum	Std. Dev.	C.V.
GS_Stocks	282.944	272.298	43.4298	654.528	135.257	0.478034
Movement_CA	426.264	263.500	1.00000	2181.00	415.635	0.975063
Movement_CA_GS	219.644	153.000	3.00000	881.000	193.173	0.879483
PGS_CA_2012	20.9440	19.7081	11.9915	38.7657	5.27027	0.251636
PGS_Wa_2012	19.6053	19.3651	13.7796	29.5461	3.31335	0.169003
PGS_WA_Diff	0.249350	0.200771	-6.43985	6.64096	1.80837	
PGS_CA_Diff	-0.00658017	-0.506220	-6.07681	9.18031	3.07498	
QGS	69479.2	59260.5	1935.46	238673.	48356.7	0.695989
Yield	13.3508	12.8000	9.15866	18.3000	2.47354	0.185272

Table A2: Summaries for QGS Model Variants

OLS estimates
Dependent variable: Movement_CA_GS

	QGS1	QGS2	**QGS3**
const	-211.5** (69.83)	-645.3** (84.46)	-262.3** (31.94)
Movement_CA	0.4893** (0.03743)	0.5081** (0.02284)	0.5072** (0.02586)
San_Joaq	109.9** (52.41)	187.4** (31.33)	323.5** (24.51)
Sta_Cruz	-92.38** (27.65)	-111.6** (19.25)	-84.68** (20.62)
Sonoma	13.35 (24.42)		
Stanislaus	128.5** (34.02)	114.0** (26.55)	
Kern		259.8** (60.51)	
Fresno		170.5** (60.38)	
DCropYear_9		60.36** (16.12)	59.94** (18.12)
DCropYear_10		79.28** (15.42)	85.55** (17.27)
DCropYear_11		35.29** (17.70)	40.94** (19.80)
DCropYear_12		64.26** (14.99)	56.07** (16.64)
DCropYear_13		44.13** (16.63)	36.96** (18.27)
n	88	149	149
Adj. R^2	0.8753	0.9175	0.8942
	F(6, 81) 102.7642**	F(11, 137) 150.6471**	F(8, 140) 157.2811**

Standard errors in parentheses
* indicates significance at the 10 percent level
** indicates significance at the 5 percent level

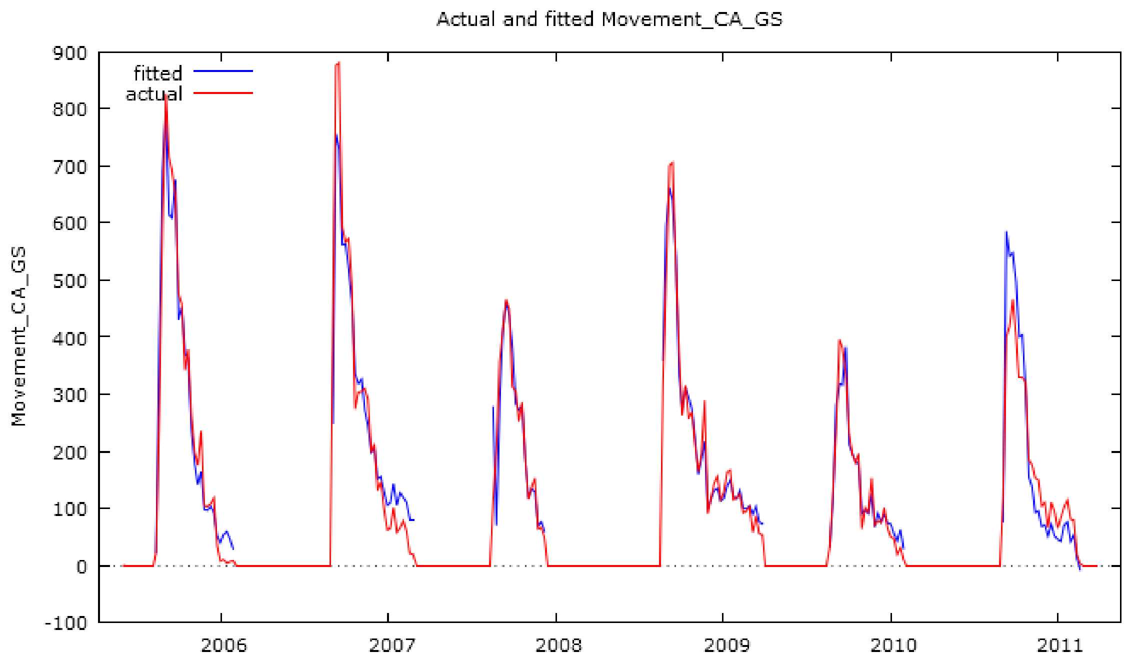
Table A3: Summaries for PGS Model Variants

OLS estimates
Dependent variable: PGS_CA_2012

	PGS1	PGS2	**PGS3**
const	193.8**	13.08**	12.34**
	(43.65)	(2.949)	(1.767)
GS_Stocks	-0.04605**	-0.03623**	-0.03724**
	(0.003868)	(0.003048)	(0.001993)
CA_Only_GS	2.114**	1.916**	1.827**
	(0.5865)	(0.4748)	(0.3750)
Net_Exports_Boxes	-2.222e-06**	-2.240e-07	
	(1.061e-06)	(8.866e-07)	
PerCap_Other	-1.360**		
	(0.3822)		
DCropYear_2	-4.482**	3.080**	3.341**
	(1.524)	(0.9854)	(0.5902)
DCropYear_3	-9.739**	-5.022**	-5.283**
	(1.313)	(0.9617)	(0.5194)
DCropYear_4	-6.002**	0.6569	
	(1.390)	(1.013)	
DCropYear_5	-9.281**	-1.221	
	(1.531)	(0.9769)	
DCropYear_6	-3.149**	1.241	
	(1.373)	(0.9126)	
DCropYear_7	-5.626**	0.01147	
	(1.261)	(0.9298)	
DCropYear_8	-9.858**	-1.461*	-1.390**
	(1.750)	(0.8526)	(0.5863)
DCropYear_9	-6.580**	3.231**	3.420**
	(1.857)	(0.9119)	(0.6528)
DCropYear_10	-4.050**	-0.07068	
	(1.336)	(0.7800)	
DCropYear_11	-9.519**	-0.7996	
	(2.351)	(0.8421)	
DCropYear_12	5.448**	3.410**	3.191**
	(1.224)	(0.9602)	(0.7743)
DCropYear_13	-6.949**	0.6588	
	(1.836)	(0.7956)	
P_All_Deflated		1.183**	1.255**
		(0.1116)	(0.09497)
QGS			4.067e-06
			(3.656e-06)
n	206	206	204
Adj. R^2	0.7862	0.8571	0.8532
	$F(17, 188)$	$F(17, 188)$	$F(9, 194)$
	45.33433**	73.32567**	132.1274**

Standard errors in parentheses
* indicates significance at the 10 percent level
** indicates significance at the 5 percent level

Figure A2: QGS3: Actual and Fitted Values, Residual Plots



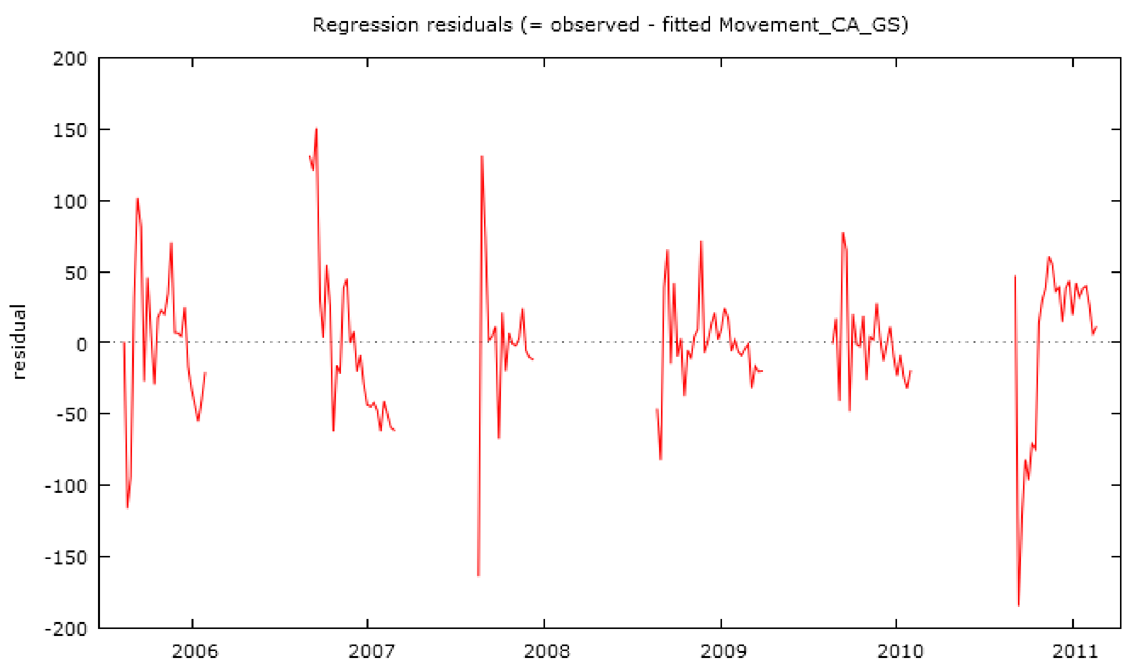
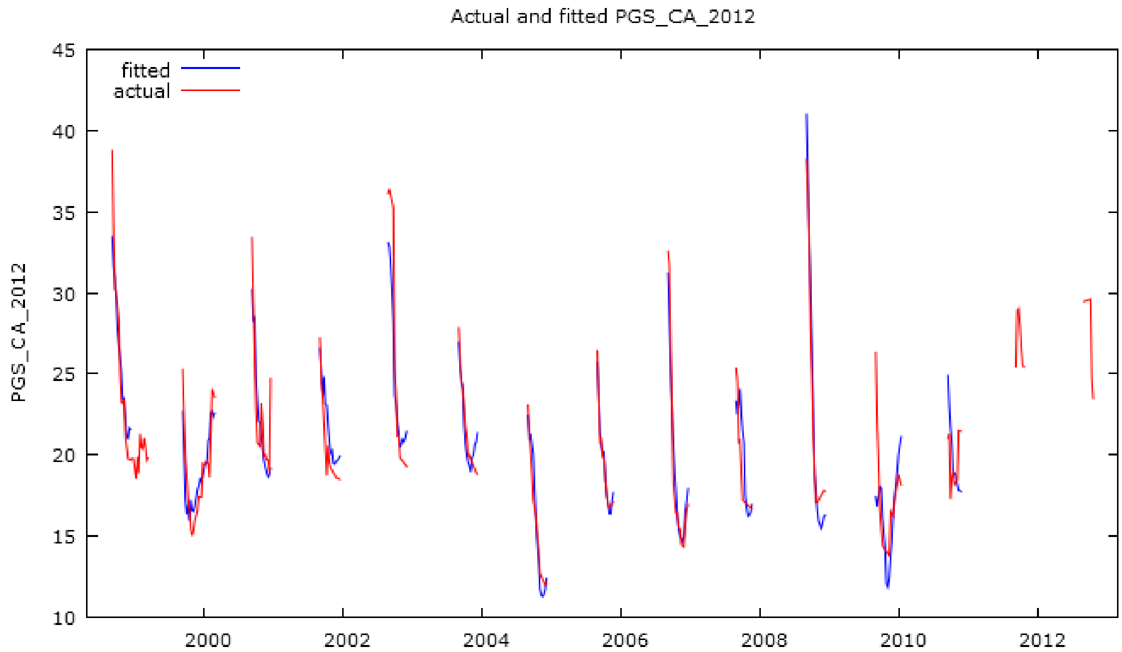


Figure A3: PGS3: Actual and Fitted Values, Residual Plots



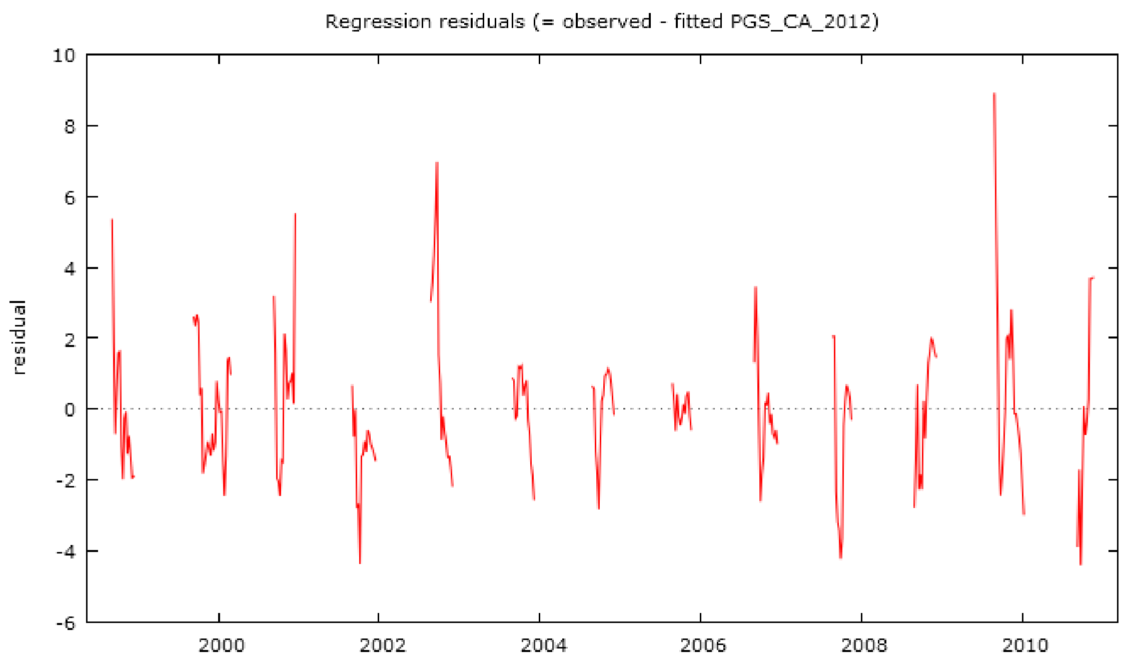


Table A3: Collinearity Tests

Variance Inflation Factors for **QGS3**
Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

Movement_CA	1.182	DCropYear_10	1.049
San_Joaq	2.618	DCropYear_11	1.043
Sta_Cruz	2.350	DCropYear_12	1.070
DCropYear_9	1.030	DCropYear_13	1.058

VIF(j) = 1/(1 - R(j)^2), where R(j) is the multiple correlation coefficient between variable j and the other independent variables

Properties of matrix X'X:
1-norm = 37670382
Determinant = 2.1340513e+017
Reciprocal condition number = 4.0322379e-008

Variance Inflation Factors for **PGS3**
Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

GS_Stocks 1.676
CA_Only_GS 1.462
DCropYear_2 1.144
DCropYear_3 1.286
DCropYear_8 1.120
DCropYear_9 1.108
DCropYear_12 1.458
P_All_Deflated 1.341
Movement_R_Alt 1.496

VIF(j) = 1/(1 - R(j)^2), where R(j) is the multiple correlation coefficient between variable j and the other independent variables

Properties of matrix X'X:
1-norm = 1.782421e+012
Determinant = 9.5606269e+029
Reciprocal condition number = 4.4901156e-013

CALIFORNIA APPLE EXPORT MARKETS

CALIFORNIA APPLE EXPORT AND DOMESTIC MARKET OVERVIEW

The California Apple Commission has culminated the final export numbers for the 2012/2013 season. California exported a total of 357,388 boxes. Out of the 17 countries that California exported to, most of them were at their normal average. California is still the third largest exporter of apples in the United States and actively receives Market Access Program dollars to help maintain these necessary export markets.

Last season, the Commission through the US Apple Export Council received $1,180,642 for the 2012/2013 program year and will receive roughly $916,447 for the 2013/2014 program year. Due to the 2013 sequester, most Foreign Agriculture Service budget allocations were decreased.

California receives several benefits from the overall funding as we are one of the largest exporters on the Council and participate in almost every export program. Below is a list of the top five countries and U.S. states that California shipped to this season. Enclosed is an overview of each market that receives MAP, TASC, or EMP funding; and all statistical shipping and destination information.

Top Five Countries		Top Five U.S. States	
1) Canada	(216,027)	1) California	(678,730)
2) Mexico	(39,703)	2) Texas	(197,916)
3) Taiwan	(36,536)	3) Michigan	(60,972)
4) Malaysia	(31,713)	4) Illinois	(54,998)
5) Thailand	(9,775)	5) Florida	(54,230)

FOREIGN AGRICULTURAL SERVICE

The Foreign Agricultural Service (FAS) helps expand and maintain foreign markets for US agricultural products by helping remove trade barriers and enforcing U.S. rights under existing trade agreements. The FAS works with foreign governments, international organizations, and the Office of the U.S. Trade Representative to establish international standards and rules to improve accountability and predictability for agricultural trade. Additionally, FAS partners up with cooperators like the US Apple Export Council to help US exporters develop and maintain agricultural export markets. FAS distributes funding to these cooperators via the Farm Bill under programs such as the Market Access Program (MAP), Technical Assistance for Specialty Crops (TASC), and Emerging Market Programs (EMP). All of these programs keep US products more competitive and counter subsidized foreign competition in the international market.

Currently, the California Apple Commission, through partnering with the US Apple Export Council, received $1,180,642 for the 2012-2013 season. This funding allocation covered 9 export markets, 6 of which California participated in. These monies funded programs such as the Mexico Inspection program, Taiwan Inspection Program, Import and Retail trade servicing within the export markets, Consumer Communication, Trade Missions, Education and Market Research. Due to the Sequester, the overall allocation to the US Apple Export Council for the 2013-2014 program year was reduced to $916,447. Most, if not all, agricultural organizations received a reduced budget.

CANADA

Canada is California's largest export market, comprising 60 percent of California's exports. When compared to last season, exports to Canada have decreased to 216,027 boxes. This is 16,761 boxes less than what was shipped in 2011-2012. California's main competition in Canada comes from Washington State, Chile, and local domestic production. Despite growing competition, the US maintains a 78.9 percent market share in the imported apple market with Chile (11.1 percent), South Africa (10 percent), New Zealand (4.2 percent) and China (3.7 percent) following far behind. While there is an opportunity in the market for USAEC shippers, holdover fruit from the southern hemisphere has increased and could continue to tighten the market window.

In 2012-2013, California Galas began arriving into Canada during the 1st week of August and remained strong until September. During this time, Canadian retailers were demonstrating a strong commitment to California due to the high quality and better color. Unfortunately, by the end of September the early onset of the Washington State harvest disrupted some of the planned USAEC promotional activities. Some of the retailers cancelled the California promotions and demos so that they could jump to Washington earlier than expected. Thankfully, enough time was provided so that the USAEC's Canadian representative was able to shift the remaining promotional funding to the retailers that were still using California product.

The retail landscape within Canada over the next few years will become increasingly more competitive. US retail giant Target plans to open 105 stores throughout Canada in 2013. Although most of these will not be fresh providers, some will be which will add to the already aggressive competition with Wal-Mart. Wal-Mart will also be increasing the number of supercenters around Canada, hoping to add roughly 40 per year.

For California, there are several issues to consider in regards to the Canadian market. First, the focus and marketing strategy of the CAC and USAEC has been to try and convince Canadian retailers to switch from Southern Hemisphere fruit to California as quickly as possible in order to get the best quality apple to the consumer. Federal dollars provided by MAP have enabled the USAEC to provide incentive by funding demos and promotions. In addition, removal of the California Granny Smith Starch-Iodine Standard has demonstrated this strategy and provided California with the ability to enter the Canadian market earlier than ever before. With the Southern Hemisphere cold storage capabilities becoming increasingly more reliable, getting retailers to switch to California as soon as possible to open the market window will become vital.

Secondly, with the introduction of new pests and diseases, Canada and the US have been working on setting up new trade policies. This could include, but is not limited to, a workplan for the exportation of apples to Canada from California. Depending what is negotiated, this could be positive as the US and Canadian governments are trying to streamline the differences in MRL's, pests, and diseases on fruits and vegetables. The CAC has been actively involved in this area and will inform the industry of any changes.

The United States Apple Export Council will assist the California Apple Commission in attaining $128,935 dollars to help maintain this market.

MEXICO

On November 30, 2012, the California/Mexico Apple Export program officially ended, completing the 2012-2013 season. In 2012-2013, California exported 39,703 boxes of apples (26,278 Granny Smith & 13,425 Gala) making Mexico the 2nd largest market for California. This was an overall increase of 18,878 boxes when compared to 2011-2012. Exports to Mexico from other USAEC member states were relatively low due to the significantly reduced crop and the elevated domestic price. Low availability of Washington State Granny Smiths advanced the sale of California Granny's and kept the market window open for a longer duration. The first load of California apples arrived in Mexico in mid-August and shipments continued until mid-November.

Apples are the 2nd most consumed fruit in Mexico, with the U.S. being the number one exporter holding a strong market share of 22%. Traditional market channels still account for 65% of produce sales but as a larger total crop volume continues to increase in the US, more movement will be needed and modern retailing will most likely be the avenue of choice. Supermarket chains such as Walmart and Soriana are gaining market share and both are opening more store locations each year. Additionally, both Walmart and Soriana find value in the small market formats and are investing significant amounts of capital in developing and expanding this section.

The USAEC's marketing strategy mainly focuses on making the importers aware of the timing and the varieties available from California. With firm competition from Washington State, Chile, and local production, promotional materials and demos are provided but the USAEC utilizes the efforts of Grupo PM (local representative) to be more informative and communicative with the Mexican retail industry.

Moreover, the Commission has been working with USDA to try and resolve the Mexico inspector issue. A stopgap measure has been installed to allow MAP funding to reimburse the Commission for the Mexico inspector costs for the 2013-2014 year. This effectively eliminated all promotional funding for this year but it allowed the border to remain open. The Commission is ultimately using all resources, including contacting the North American Plant Protection Organization (NAPPO), in hopes of eliminating this costly expense. Currently, negotiations with Mexico are ongoing.

The United States Apple Export Council will assist the California Apple Commission in attaining $95,000 dollars to help maintain this market.

SOUTH EAST ASIA

South East Asia (SEA), a region which includes Malaysia, Thailand, Indonesia, Singapore, Vietnam, and the Philippines, is one of California's largest markets. The South East Asia market is classified as a region because the USAEC believes there are clear marketing relationships and distinct cohesiveness between retailers in these countries. In 2012-2013, California exported 55,659 boxes of apples to the SEA. This is a 13,257 box increase when compared to 2011-2012.

Although traditional retail trade accounts for the bulk of US apple shipments, modern retail outlets are expanding. This is true in not only the larger, more developed cities but expansion is also happening in the secondary markets and smaller towns.

The main competition for California remains Washington State and China. With China's ability to provide year around availability, low prices, and close proximity, China maintains the largest market share. The SEA region is beginning to demand higher quality and food safety assurances which could diminish China's market share in the future. Over the last few years, the marketing strategy for the USAEC in the SEA was to maximize the efforts of the USAEC's representatives during the marketing window of California. California apples were positioned as a high quality apple with exceptional size and color. This made it possible to distinguish and justify California apples when compared to the cheaper Chinese version. In 2012, the USAEC's efforts included providing POS materials, performing promotional demos, and participating in Asia Fruit Logistica trade show.

The Fuji variety still remains the most popular apple in the SEA region but it is not California's number one variety exported there. For California, the Granny Smith is the most popular apple exported to the SEA region. The California Granny Smith with its exceptional color, high quality taste, price, and availability, make it highly desirable. In the past, the USAEC has pushed the California Granny Smith with no real focus on other varieties due to availability and logistical constraints. Recently, the USAEC has begun focusing on introducing new varieties into the market in an attempt to expand the region to other USAEC member states. Varieties such as Cripps Pink, Gala, and Empire were all viewed positively and will be showcased more in 2013. Promotions and incentives will be provided to the retailers to encourage more shelf space for more varieties.

In 2013, the United States Apple Export Council will assist the California Apple Commission in attaining $113,697 dollars to help maintain this market.

INDIA

India, a country that has a massive middle class population (250 million people), is set to become one of the largest importers of apples in the world in the near future. Recognizing the growth opportunity, the USAEC has applied for MAP, TASC, and EMP funding to help develop opportunities for the US apple industry and for California shippers. However, because the Indian distribution and handling channels are still being established, there are limitations. The Indian government and retailers are aware of the situation and are quickly trying to find a solution.

For now, the CAC considers India to be a niche market at best for California exporters. Although the market is clearly growing and the demand for new dynamic varieties that do not directly compete with the domestic/local production is expanding, the logistics of shipping and high risk involved makes large volumes from California difficult. That being said, the CAC does see value for other USAEC member states. In 2010-11, the export volumes were nearly 200,000 boxes, making India one of the fastest growing markets for USAEC. India could provide a perfect outlet for large volumes of apples in the case of an exceedingly large US apple crop. If this were to happen, exporting apples to India could alleviate pressure on the domestic market and help keep prices sustainable.

Through the use of EMP funds, the CAC has made contact with most of the significant importers within India. Over 600 retail outlets are scheduled to be built in the future, providing the massive middle class the maximum opportunity to buy quality produce. The USAEC's marketing strategy uses a simplistic approach which is to maintain a very targeted and concentrated effort aimed at the middle class. Major retail customers in large regions such as New Delhi, Mumbai, and Chennai will be contacted and offered promotional and educational materials. Medium size cities including but not limited to Ahmedabad, Chandigarh, and Pune will also be included. Although the USAEC will never be able to service the entire Indian market, US apples are highly regarded and the USAEC will look to grasp onto this notion in specific regions. In October of 2013, a reverse trade mission will take place with several major retailers visiting the Eastern U.S.

The United States Apple Export Council will assist the California Apple Commission in attaining $125,667 dollars to help maintain this market.

BRAZIL

In 2012-2013, the US Apple Export Council began to start applying market access dollars into Brazil. The USAEC views Brazil as a very probable market for the Eastern US states especially with the 2016 Olympics and 2014 World Cup being held there over the next couple of years. The USAEC will be focusing on promoting and exporting red apple varieties. It is believed that the moderate volumes, sizes, and pricing available in the Eastern USAEC States could fulfill a limited window before Washington State begins.

Although the US Apple Export Council member states have not shipped to Brazil thus far, Washington State has seen some success. The US Apple Export Council is anticipating that if the Eastern US States have a large crop and Washington State continues to have large crop volumes, a new market will be needed to alleviate the domestic pressure. The marketing strategy for the USAEC in Brazil is to identify key importers and introduced the Eastern US shippers as niche suppliers with excellent quality. Eventually, the USAEC will begin introducing different varieties to the expanding modern retail market. This will be done on a limited basis and will be designed to slowly build upon a few key shippers from the USAEC.

The main competition for US apple exports will come from holdover from Argentina, Chile, and fresh product from European producers. Argentina's cold storage capabilities are insufficient to sustain Brazil's demand, whereas Chile has developed a suitable cold storage system but has lacked the overall volume in recent years. Europe exports have increased in recent years and now have a strong foothold on the market. European competition which includes Italy, France, and Portugal, has significant advantages when compared to the US. Besides no tariffs, European freight is less expensive and Brazil has limited phytosanitary grievances against Europe.

For California, there is little opportunity in Brazil due to the cold treatment requirements, shipping expenses, and the limited seasonal window between the Southern Hemisphere and Washington State. Although the US Apple Export Council will consider Brazil an option, California does not consider it a priority.

The United States Apple Export Council will assist the California Apple Commission in attaining $52,000 dollars during the 2013-2014 season to help set up and explore this market.

RUSSIA

Russia is currently the world's largest consumer and importer of apples. In 2012, Russia imported just over 1.2 million tons of apples. The majority of US apple exports to Russia come from Washington State via the Eastern Port of Vladivostok. Washington State considers Russia a high priority because of the volume of Red Delicious that Russia can import. Other red varieties are also seeing success. The US apple industry maintains a reputation of high color and high quality within the Russian retail sector which has contributed to the increase in volumes over the last several years. Being that the USAEC's Eastern States have easier access to St. Petersburg, Moscow, and other Western Russia markets, the USAEC began expressing interest in expanding the market. Trade volumes have been limited but opportunities are increasing.

A positive trend for the increase in apple trade is that, per the USAEC, in 2012 Russia was admitted as the World Trade Organization's 156th member. Accession is expected to have gradual effect on phytosanitary barriers that tended to restrict the flow of trade. On the tariff side, after accession import duties on apples were significantly reduced. Between January 1 and July 31, the customs duty on apples is 0.06 euro per 1 kg. From August 1 – December 31 import duty on Golden Delicious and Granny Smith apples is 0.02 euro/kilo, while other varieties are cleared under 0.01euro/kilo customs duty. This becomes an advantage for global apple exporters, including USAEC members, against domestic apple crop. The market strategy for the USAEC is to motivate increased handling of specific USAEC apple varieties throughout the entire USAEC season. Activities include trade servicing, trade missions and shows, promotional activities, and educational programs.

For California, Russia remains a very low market priority. Funding for this market was decreased dramatically by the USAEC due to sequester. The East Coast members of the US Apple Export Council consider the Russian market a developing and important market, but with limited resources it should not be fully funded at this time. Therefore, the USAEC requested that the Foreign Agricultural Service decrease its contribution from $47,000 in 2012 to $11,000 dollars in 2013. This was done in order to help maintain this market albeit on a very limited basis.

CENTRAL AMERICA

Central America is a market that the US Apple Export Council has been focused on developing mainly for US Eastern apple varieties. Although this is not a large market for California, it does demonstrate some potential for smaller sizes. Over the last several years, due to the increase in demand from the domestic market California has seen a decline in exports to the Central American region. In 2012-2013, California hit its lowest exported total, exporting 3,501 boxes of apples to Central America (split between Granny Smith and Gala varieties). In contrast, in 2011-2012 California exported 13,756 boxes to Central America. Even though the demand for California apples is relatively high in this region, the prices needed to purchase the apples have discouraged Central American buyers. To that point, the US Apple Export Council has supported marketing the California apple as a high quality and premium brand that can justify the higher retail price.

In addition to high California prices, another major problem that California is facing when exporting to Central America is the reluctance of the Central American consumer to switch from the traditional Red and Golden Delicious apple varieties. Grupo PM, the US Apple Export Council's representative, has been introducing and educating the Central American retailers and consumers on the availability and desirability of other varieties in an effort to convince the Central American retailers to promote a wider range of apples.

Due to the forecasting of large apple volumes from US Apple Export Council member states and Washington State, the US Apple Export Council is determined to maintain and expand new markets that are currently receiving red apple varieties. The Central American region falls into this category. In October 2013, a reverse trade mission will be held with Central American buyers. The Central American buyers will visit the Eastern U.S. States the week before the Produce Marketing Association trade show.

The United States Apple Export Council will assist the California Apple Commission in atttaining $118,398 dollars to help maintain this market.

CALIFORNIA APPLE DOMESTIC AND EXPORT STATISTICS

CALIFORNIA APPLE COMMISSION

DOMESTIC & EXPORT REPORTS
2012 – 2013 SEASON

- **US Apple Statistics**
- **California's Top 5 States**
- **Export Totals**
- **Pack Out Report**

CALIFORNIA APPLE COMMISSION 1996 - 1997

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	22507	16075	230		98		**38,910**
ALASKA	448						**448**
ARIZONA	21593	46632	3357	147	1000	3796	**76525**
ARKANSAS	3112	3566	2280		238	49	**9245**
CALIFORNIA	315087	479889	340179	3925	1677	66745	**1207502**
COLORADO		22633	14982			196	**37811**
DIST. OF COLUMBIA	1055	49	1964				**3068**
FLORIDA	26760	67166	15002		389	1198	**110515**
GEORGIA	15188	26530	4851	132	304		**47005**
HAWAII	1539	1394	17352			2700	**22985**
IDAHO	215	622	74		24		**935**
ILLINOIS	14165	103930	25936			1664	**145695**
INDIANA	5138	13830	686	171			**19825**
IOWA	3911	15227	1546	309	392		**21385**
KANSAS		5782	2170	37			**7989**
KENTUCKY	12470	11499	1755		683		**26407**
LOUISIANA	9352	3543	1487	2		589	**14973**
MAINE		9499					**9499**
MARYLAND	20568	48447	11410	1	392	196	**81014**
MASSACHUSETTS	11303	122853	1165	147	245		**135713**
MICHIGAN	11743	26532	3979	42	818	1056	**44170**
MINNEOSOTA	7161	19530	2607	371		84	**29753**
MISSISSIPPI	3475	4374	1263		196		**9308**
MISSOURI	5499	31124	1866		134	325	**38948**
MONTANA	235	817					**1052**
NEBRASKA	98	1594	193		98		**1983**
NEVADA	196	4736	393				**5325**
NEW HAMPSHIRE	196	435					**631**
NEW JERSEY	5722	43180	3156			147	**52205**
NEW MEXICO	345	698	804			1760	**3607**
NEW YORK	25677	85557	98349	648	2359	2270	**214860**
NORTH CAROLINA	7160	15481	921	196	157		**23915**
NORTH DAKOTA	25	1212	147				**1384**
OHIO	19648	42878	2151	126	759	147	**65709**
OKLAHOMA	6351	10101	182		28	21	**16683**
OREGON	8205	17212	672	5		581	**26675**
PENNSYLVANIA	20246	63245	10951	99	356	177	**95074**
RHODE ISLAND		462					**462**
SOUTH CAROLINA	5287	1936	931			1302	**9456**
SOUTH DAKOTA		49					**49**
TENNESSEE	5500	10903	1225		392	147	**18167**
TEXAS	57264	99018	20311	89	435	7643	**184760**
UTAH	4523	27766	514				**32803**
VIRGINIA	4113	13336	3047				**20496**
WASHINGTON	22677	24411	11856			2350	**61294**
WEST VIRGINIA	392	1338	98				**1828**
WISCONSIN	9839	23839	2174	6447	637	686	**43622**
TOTAL	**715,988**	**1,570,930**	**614,216**	**12,894**	**11,811**	**95,829**	**3,021,668**

CALIFORNIA APPLE COMMISSION 1997 - 1998

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	9464	21890	287				**31641**
ALASKA	420		266	539			**1225**
ARIZONA	43270	15377	3294	392		1091	**63424**
ARKANSAS	3087	11509	4356				**18952**
CALIFORNIA	402223	492751	476264	20035	488	82122	**1473883**
COLORADO	27819	33391	8123	4300		1276	**74909**
CONNECTICUT	2319	2975	49				**5343**
DIST. OF COLUMBIA		344	4037			18	**4399**
FLORIDA	36244	72778	18125	330		1239	**128716**
GEORGIA	13001	76736	9037	302	214	245	**99535**
HAWAII	2375	1420	24895			1475	**30165**
IDAHO	1029	259	99				**1387**
ILLINOIS	42143	84004	19355	989	147	3042	**149680**
INDIANA	5278	11270	881	433	355	55	**18272**
IOWA	1568	10234	875				**12677**
KANSAS	4424	6054	1130	800		8	**12416**
KENTUCKY	9078	18394	3558	1035			**32065**
LOUISIANA	322	2421	175	167		343	**3428**
MAINE	196	1421					**1617**
MARYLAND	27531	33722	22875	62	98	392	**84680**
MASSACHUSETTS	12053	105464	3485	108	49	2953	**124112**
MICHIGAN	17508	36142	7410	1036	543	313	**62952**
MINNESOTA	4610	18136	3295	672	821	724	**28258**
MISSISSIPPI	7528	10603	2882			490	**21503**
MISSOURI	9326	28023	6234	966	653	1426	**46628**
MONTANA	315	676	196	364			**1551**
NEBRASKA	407	1823	50				**2280**
NEVADA	1549	1963	504	148		133	**4297**
NEW HAMPSHIRE		490					**490**
NEW JERSEY	7934	36384	5894	315	34	1436	**51997**
NEW MEXICO	1007	931	539			260	**2737**
NEW YORK	41645	147612	77306	2432	1519	2316	**272830**
NORTH CAROLINA	37252	10031	3754	142		1402	**52581**
NORTH DAKOTA	497	958				290	**1745**
OHIO	24643	54603	6182	3203		526	**89157**
OKLAHOMA	5505	15540	1475	64	490	2080	**25154**
OREGON	7959	10141	355		98	887	**19440**
PENNSYLVANIA	30489	68296	6508	529		975	**106797**
RHODE ISLAND	24	98					**122**
SOUTH CAROLINA	1323	8210	1029			375	**10937**
SOUTH DAKOKTA		1	67				**68**
TENNESSEE	6020	17537	4041				**27598**
TEXAS	86163	85827	21948	2091	196	3706	**199931**
UTAH	7475	37284	2315				**47074**
VIRGINIA	6435	9226	3136	182		84	**19063**
WASHINGTON	13287	15224	14823	163	196	1010	**44703**
WEST VIRGINIA	49	50	104		20		**223**
WISCONSIN	12776	24633	3577	490	796	49	**42321**
TOTAL	**975,570**	**1,642,856**	**774,790**	**42,289**	**6,717**	**112,741**	**3,554,963**

CALIFORNIA APPLE COMMISSION 1998 - 1999

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	3663	2004	76				**5743**
ALASKA		21		543			**564**
ARIZONA	25077	21075	12986	1938		1	**61077**
ARKANSAS		2228	245				**2473**
CALIFORNIA	323538	452379	379349	45212	334	39117	**1239929**
COLORADO	16275	26604	3651	8091	680		**55301**
CONNECTICUT	366	2644					**3010**
DIST. OF COLUMBIA				196			**196**
FLORIDA	29947	32535	24056	3700		414	**90652**
GEORGIA	5388	11338	4054	1030		147	**21957**
HAWAII	504	26	13123	61		33	**13747**
IDAHO		1127		135			**1262**
ILLINOIS	13128	68592	4504	2599		2868	**91691**
INDIANA	2767	12872	447	1381			**17467**
IOWA	774	2565	719	985			**5043**
KANSAS	1470	2471	434	3312		490	**8177**
KENTUCKY	9612	7851	62	539			**18064**
LOUISIANA	2835	135		49			**3019**
MAINE	539	12335	205	516			**13595**
MARYLAND	6436	22908	3663	833		378	**34218**
MASSACHUSETTS	8055	85228	4147		3351	3221	**104002**
MICHIGAN	4868	16552	1232	1509			**24161**
MINNESOTA	2558	18551	1125	496	668	231	**23629**
MISSISSIPPI	1862	3924	1040			2033	**8859**
MISSOURI	2997	11091	3351	796		69	**18304**
MONTANA	294			98			**392**
NEBRASKA	1			98			**99**
NEVADA	952	1767	821			385	**3925**
NEW HAMPSHIRE	241	441					**682**
NEW JERSEY	3904	29125	2314	723		245	**36311**
NEW MEXICO	1276	1845	190				**3311**
NEW YORK	31889	79417	41668	3693		686	**157353**
NORTH CAROLINA	9349	5143	745	542		1299	**17078**
NORTH DAKOTA	378		49				**427**
OHIO	12232	22863	2350	3136		1472	**42053**
OKLAHOMA	2315	4126	440	388		147	**7416**
OREGON	2895	8961	702	491		99	**13148**
PENNSYLVANIA	19315	35920	2322	1813		433	**59803**
RHODE ISLAND	1553	245	539				**2337**
SOUTH CAROLINA	1795	735	2			980	**3512**
TENNESSEE	2053	8458	5273				**15784**
TEXAS	40910	68323	20490	7426		3759	**140908**
UTAH	6433	11635	3031	1029			**22128**
VIRGINIA	1701	2254	637	236		489	**5317**
WASHINGTON	3376	3312	1009			83	**7780**
WISCONSIN	5946	14872	4659	2146		238	**27861**
TOTAL	**611,467**	**1,116,498**	**545,710**	**95,740**	**5,033**	**56,096**	**2,433,765**

CALIFORNIA APPLE COMMISSION 1999 - 2000

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	3157	6,090	546	392	147		**10332**
ALASKA	44			577		1	**622**
ARIZONA	31318	48612	5842	4460	98	1	**90331**
ARKANSAS	1948	5384					**7332**
CALIFORNIA	332295	591431	454053	123775	4316	74129	**1579999**
COLORADO	22805	39460	9160	19431	170	386	**91412**
CONNECTICUT		7555	147				**7702**
DIST. OF COLUMBIA		490					**490**
FLORIDA	42473	79015	22379	10249	343	1019	**155478**
GEORGIA	12764	15432	6662	2608	516		**37982**
HAWAII	569	280	19504	49			**20402**
IDAHO	147	2435	1176		14	63	**3835**
ILLINOIS	25629	70083	19607	8573	803	1155	**125850**
INDIANA	9359	28823	1571	3965		193	**43911**
IOWA	2221	7353	1232	938			**11744**
KANSAS	2754	4430	1298	3523	147		**12152**
KENTUCKY	10070	23318	2514	2009			**37911**
LOUISIANA	521	971	504	49			**2045**
MAINE	1568	13402	392	1323			**16685**
MARYLAND	10507	33484	5749	196	441	1043	**51420**
MASSACHUSETTS	23745	140487	5870	16488	560	1906	**189056**
MICHIGAN	19541	38308	4917	5715	860	148	**69489**
MINNESOTA	4106	14594	1384	2207	173	428	**22892**
MISSISSIPPI	2333	10694	98	971			**14096**
MISSOURI	2646	13144	3242	6764	1	437	**26234**
MONTANA	98	99	177				**374**
NEBRASKA	88	648	814	49			**1599**
NEVADA	1100	2819	2540	354		126	**6939**
NEW HAMPSHIRE	98		140	42			**280**
NEW JERSEY	7725	28840	4910	1178	51	244	**42948**
NEW MEXICO	1880	2802		478			**5160**
NEW YORK	27401	153840	86100	9498	147	1036	**278022**
NORTH CAROLINA	11803	12474	944	1771	324		**27316**
OHIO	20858	24747	8124	5195	1585	160	**60669**
OKLAHOMA	4843	10219	2247	1166	147		**18622**
OREGON	3810	15293	5760	980	490	430	**26763**
PENNSYLVANIA	27551	64540	10178	4312	1484	1691	**109756**
RHODE ISLAND		1778	49				**1827**
SOUTH CAROLINA	4404	3283	1428	916			**10031**
TENNESSEE	3465	10636	6316	115	49		**20581**
TEXAS	59074	90626	14770	9787	1418	2814	**178489**
UTAH	5218	15609	4337	994		490	**26648**
VIRGINIA	3806	8653	1991	1041	49		**15540**
WASHINGTON	16074	7034	414	7109		1264	**31895**
WISCONSIN	7808	12493	2216	1282	1392		**25191**
TOTAL	**769,624**	**1,661,708**	**721,302**	**260,529**	**15,725**	**89,164**	**3,518,052**

CALIFORNIA APPLE COMMISSION 2000 - 2001

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	2441	18260	302	1407			**22410**
ARIZONA	37912	43143	8294	8566		575	**98490**
ARKANSAS	2835	2328	854	539			**6556**
CALIFORNIA	281214	488193	302509	128114	6012	76307	**1282349**
COLORADO	17966	28867	791	11634	136	197	**59591**
CONNECTICUT	1055	7398	55		98		**8606**
DIST. OF COLUMBIA	135	392					**527**
FLORIDA	17950	54737	17333	4419		24	**94463**
GEORGIA	8355	17803	1665	457		98	**28378**
HAWAII	703	267	10708			124	**11802**
IDAHO		370	343				**713**
ILLINOIS	16269	35486	5594	3589	1078	1399	**63415**
INDIANA	7562	21803	401	1948	7	497	**32218**
IOWA	2716	9022	196	931	441		**13306**
KANSAS	3111	3220	2508	1701			**10540**
KENTUCKY	6360	18170	1505	3748			**29783**
LOUISIANA	1059	3411	470		542		**5482**
MAINE	980	12843	735	1960			**16518**
MARYLAND	5439	33952	4658	392	196	1617	**46254**
MASSACHUSETTS	14795	64636	5508	3501	686	1002	**90128**
MICHIGAN	26306	47570	7992	4243	294		**86405**
MINNESOTA	5055	17327	1303	1226	390	21	**25322**
MISSISSIPPI	2142	4448	1263				**7853**
MISSOURI	7765	19331	1682	4963	245		**33986**
MONTANA	126	586	119	98			**929**
NEBRASKA	835	1197	1147	893			**4072**
NEVADA	2845	1614	2491	1017		778	**8745**
NEW JERSEY	2854	25008	2396	1821	57	449	**32585**
NEW MEXICO	1568	1529					**3097**
NEW YORK	23528	131988	69287	10506	834	3504	**239647**
NORTH CAROLINA	7855	6613	1597	539	392	294	**17290**
NORTH DAKOTA	56	966	49	49			**1120**
OHIO	16690	27398	5824	1589	49	168	**51718**
OKLAHOMA	4080	8099	1102	933		490	**14704**
OREGON	3349	14015	1295	21		49	**18729**
PENNSYLVANIA	7911	46448	2922	2176	147	33	**59637**
RHODE ISLAND		336					**336**
SOUTH CAROLINA	2362	8030	420	546			**11358**
TENNESSEE	3501	7609	7566	287			**18963**
TEXAS	62678	83886	11305	28787	1544	5318	**193518**
UTAH	5955	6840	532	3209			**16536**
VIRGINIA	1862	11540	280	931		1225	**15838**
WASHINGTON	6324	21580	2493	71	2	1940	**32410**
WEST VIRGINIA							
WISCONSIN	4105	14798	1313	4946	13150		**38312**
TOTAL	**628,629**	**1,373,057**	**488,807**	**241,757**	**13,150**	**96,109**	**2,854,639**

CALIFONRIA APPLE COMMISSION 2001 - 2002

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	4340	10408	343	98			**15189**
ARIZONA	31079	24599	15709	6605	29	21	**78042**
ARKANSAS	1939	2545					**4484**
CALIFORNIA	231229	472875	305385	90839	6772	39487	**1146587**
COLORADO	8412	9590	5858	3446	140	147	**27593**
CONNECTICUT		3822	486				**4308**
DELAWARE				49			**49**
DIST. OF COLUMBIA		343	98				**441**
FLORIDA	23446	48824	19912	4205	343	147	**96877**
GEORGIA	11611	15735	10466	49	420		**38281**
HAWAII	882	147	6541	200			**7770**
IDAHO	588	903	245				**1736**
ILLINOIS	24914	33609	7019	2499	503	824	**69368**
INDIANA	13126	30941	3582	2429	490	35	**50603**
IOWA	4389	1690	98	490			**6667**
KANSAS	2303	850	2107	3052	245		**8557**
KENTUCKY	5348	18986	5261				**29595**
LOUISIANA	1893	8301	1717		321		**12232**
MAINE	833	19451	245	147			**20676**
MARYLAND	14705	40463	5639	2625	83	1903	**65418**
MASSACHUSETTS	15547	77285	6027	3161	2543	1333	**105896**
MICHIGAN	18707	34414	7123	98	523	210	**61075**
MINNESOTA	2286	11280	1118	536	1025	837	**17082**
MISSISSIPPI	1659	1694	42				**3395**
MISSOURI	3241	12040	4177	2922	98		**22478**
MONTANA	441	448	613		98		**1600**
NEBRASKA	684	433	727	637			**2481**
NEVADA	1329	3200	3592	49			**8170**
NEW JERSEY	13441	9809	8576	4854		668	**37348**
NEW MEXICO	2341	917	336				**3594**
NEW YORK	19409	117976	333158	2695		78	**473316**
NORTH CAROLINA	12311	1912	1811	246	954	245	**17479**
NORTH DAKOTA			98				**98**
OHIO	14546	15087	4700	572	329	147	**35381**
OKLAHOMA	3625	5672	2509	1194	98		**13098**
OREGON	4655	5474	3374	1	441	133	**14078**
PENNSYLVANIA	22734	25600	8959	490	98		**57881**
SOUTH CAROLINA	2905	8309	1862				**13076**
TENNESSEE	6367	11293	2024	245	178		**20107**
TEXAS	61686	111827	13568	21005	2802	1490	**212378**
UTAH	9570	4775	2045	2591	49		**19030**
VIRGINIA	2689	5089	1827	147	128		**9880**
WASHINGTON	11095	10223	14216	1713	631	248	**38126**
WISCONSIN	5371	7284	2817	294	98		**15864**
TOTAL	**617,676**	**1,226,123**	**816,010**	**160,183**	**19,439**	**47,953**	**2,887,384**

CALIFORNIA APPLE COMMISSION 2002 - 2003

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	5826	16167	1833	98			**23924**
ALASKA							
ARIZONA	35402	48598	6616	10476	272	42	**101406**
ARKANSAS		875					**875**
CALIFORNIA	261499	720385	197897	118770	12733	37667	**1348951**
COLORADO	12106	30718	3654	15124	1743	336	**63681**
CONNECTICUT		8904		721	513		**10138**
DIST. OF COLUMBIA		1029	154				**1183**
FLORIDA	39234	61488	12884	5710	427	145	**119888**
GEORGIA	15542	41444	12046	2040			**71072**
HAWAII	1932	1616	2657				**6205**
IDAHO	196	2715	836	135		84	**3966**
ILLINOIS	31659	92750	12637	2485	343	1797	**141671**
INDIANA	20990	56696	4774	2341	196	1840	**86837**
IOWA	5610	20780	1748	4717			**32855**
KANSAS	3667	4370	539	5739	49	1658	**16022**
KENTUCKY	6682	30356	1898	421	360		**39717**
LOUISIANA	2279	7789	2362	561			**12991**
MAINE	5343	14745	392	140			**20620**
MARYLAND	20091	38306	7808		136		**66341**
MASSACHUSETTS	21589	88556	8393	5772	147	1564	**126021**
MICHIGAN	24509	50300	11131	5911	605	403	**92859**
MINNESOTA	7916	34949	4359	1667	33	9001	**57925**
MISSISSIPPI	693	1771	300	980			**3744**
MISSOURI	12701	45026	7779	3858			**69364**
MONTANA	343	602	1240	21			**2206**
NEBRASKA	1191	2044	525	413	494		**4667**
NEVADA	588	1753	165	196	1078		**3780**
NEW JERSEY	19904	65028	14363	1159	136	613	**101203**
NEW MEXICO	2117	230	189				**2536**
NEW YORK	33379	133709	16841	7148		547	**191624**
NORTH CAROLINA	15983	15028	3430	948			**35389**
NORTH DAKOTA	147	350	1029				**1526**
OHIO	19920	36601	9339	5921	198	98	**72077**
OKLAHOMA	3613	3636	735	1088	98		**9170**
OREGON	3151	11209	5114	4000	1041	1922	**26437**
PENNSYLVANIA	21034	69067	3647	4174	363	26	**98311**
RHODE ISLAND		441					**441**
SOUTH CAROLINA	3876	7789	147				**11812**
TENNESSEE	6476	16989	6027	6824	500		**36816**
TEXAS	57028	160295	21981	33131	1315	5278	**279028**
UTAH	8988	12078	3676	8375	331		**33448**
VIRGINIA	8764	22400	2684	1099			**34947**
WASHINGTON	16099	40904	10950	21498	1189	267	**90907**
WEST VIRGINIA			196				**196**
WISCONSIN	8770	18015	3740	8122	343		**38990**
TOTAL	**766,837**	**2,038,501**	**408,715**	**291,783**	**24,643**	**63,288**	**3,595,767**

CALIFORNIA APPLE COMMISSION 2003 - 2004

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	5178	16820	5881				**27879**
ALASKA		413					**413**
ARIZONA	48778	42208	7152	5437	147		**103722**
ARKANSAS	89	494	441				**1024**
CALIFORNIA	409464	601262	225482	118937	4341	50005	**1409491**
COLORADO	8563	32961	1577	6624	1297	1098	**52120**
CONNECTICUT	416	8332			98	172	**9018**
DIST. OF COLUMBIA		217					**217**
FLORIDA	36690	95429	12781	6716		1867	**153483**
GEORGIA	13932	45048	7064	2723	658	712	**70137**
HAWAII	1710	2179	12737		5	1268	**17899**
IDAHO	533	3379	699	147		392	**5150**
ILLINOIS	34315	78462	10148	3816	735	2829	**130305**
INDIANA	16332	39194	7408	928	303	188	**64353**
IOWA	3917	16211	4887	318	441		**25774**
KANSAS	4001	5881	1037	968	390		**12277**
KENTUCKY	5387	25848	4630	65			**35930**
LOUISIANA	3532	13867	882				**18281**
MAINE	1421	21631	1176	1176			**25404**
MARYLAND	21144	26452	3024	7751		931	**59302**
MASSACHUSETTS	8330	79177	5278	2882	761	98	**96526**
MICHIGAN	43849	56032	10689	9801			**120371**
MINNESOTA	5292	43787	1981	774	192	2631	**54657**
MISSISSIPPI	3075	4656	10	654			**8395**
MISSOURI	24598	34633	8181	6306	334		**74052**
MONTANA		434					**434**
NEBRASKA	98						**98**
NEVADA	2421	5350	1008		694	896	**10369**
NEW JERSEY	20914	36597	10517	196	241	755	**69220**
NEW MEXICO	20	2007	343				**2370**
NEW YORK	23393	155948	24096	7882		776	**212095**
NORTH CAROLINA	5108	14167	2168		147	1078	**22668**
NORTH DAKOTA		112					**112**
OHIO	23397	36684	6406	11022			**77509**
OKLAHOMA	1392	5496	219	19			**7126**
OREGON	6833	24384	1907	181	66	5289	**38660**
PENNSYLVANIA	14773	54816	2896	1715	294	2464	**76958**
RHODE ISLAND		294					**294**
SOUTH CAROLINA	2940	6062	1911				**10913**
TENNESSEE	11426	17119	2728	6310		6182	**43765**
TEXAS	84111	171040	24150	39570	2058	7261	**328190**
UTAH	1212	13731	4058	8520	361	631	**28513**
VIRGINIA	1772		1346	245		162	**3525**
WASHINGTON	30376	63272	18439	5367	89	3545	**121088**
WISCONSIN	4665	15148	1064	27	40		**20944**
WYOMING	294						**294**
TOTAL	**935,691**	**1,917,234**	**436,401**	**257,077**	**13,692**	**91,230**	**3,651,325**

CALIFORNIA APPLE COMMISSION 2004 - 2005

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	4733	20296	147				**25176**
ARIZONA	46215	22354	15932	15877	1899		**102277**
ARKANSAS				490			**490**
CALIFORNIA	481834	572472	202152	99255	15826	14180	**1385719**
COLORADO	10029	8384	2595	5893	1247	588	**28736**
CONNECTICUT	4141	6938	441	343			**11863**
DIST. OF COLUMBIA	2009	588					**2597**
FLORIDA	32807	67383	3739	539	49	147	**104664**
GEORGIA	15447	35147	4131	4765	70	385	**59945**
HAWAII	3961	773	7904				**12638**
IDAHO	1063	152					**1215**
ILLINOIS	19231	48388	4923	5151	284	984	**78961**
INDIANA	21948	13026	1647	1720	83	151	**38575**
IOWA	1911	12488	5767	1813			**21979**
KANSAS	829	1190	1630	660	300		**4609**
KENTUCKY	9343	7929	1001	2100	98		**20471**
LOUISIANA	3490	10362	877	343	147		**15219**
MAINE		21048		147			**21195**
MARYLAND	10490	29562	3981	5096			**49129**
MASSACHUSETTS	7385	50616	2464	2456	588	898	**64407**
MICHIGAN	42482	53382	11655	5660		735	**113914**
MINNESOTA	10443	37584	3163	1519	389	897	**53995**
MISSISSIPPI		6178	253	441			**6872**
MISSOURI	27428	30857	2915	3237	245		**64682**
MONTANA	2						**2**
NEBRASKA	399	959	900				**2258**
NEVADA	1764	2067	1684		98		**5613**
NEW JERSEY	12626	35047	8796	1647	379	682	**59177**
NEW MEXICO		245	56				**301**
NEW YORK	10546	140756	10677	10143	23		**172145**
NORTH CAROLINA	8702	1822	1890				**12414**
NORTH DAKOTA	98	49					**147**
OHIO	24331	31186	6976	4161			**66654**
OKLAHOMA	660	1676		490			**2826**
OREGON	3960	3403	274		226	3117	**10980**
PENNSYLVANIA	22595	50702	1975	1174		802	**77248**
SOUTH CAROLINA	2142	4475	770				**7387**
SOUTH DAKOKTA	147						**147**
TENNESSEE	17490	14881	1481	2892	480		**37224**
TEXAS	109934	123195	13452	41016	654	833	**289084**
UTAH	1759	2262	2414	833	120		**7388**
VERMONT	21					49	**70**
VIRGINIA	3450	2770	49				**6269**
WASHINGTON	14875	42601	9059	14481	613	281	**81910**
WISCONSIN	7421	6995	885	196			**15497**
TOTAL	**1,000,141**	**1,522,188**	**338,655**	**234,538**	**23,818**	**24,729**	**3,144,069**

CALIFORNIA APPLE COMMISSION 2005 - 2006

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	8590	12614		98			**21302**
ARIZONA	35616	46533	5976	6925	3224	966	**99240**
CALIFORNIA	345553	586557	233198	86394	10523	19017	**1281242**
COLORADO	12876	15412		2628	1720	685	**33321**
CONNECTICUT	5818	9423	73				**15314**
DIST. OF COLUMBIA		1029					**1029**
FLORIDA	19077	62217	13679	1456	27	367	**96823**
GEORGIA	11679	42381	5771	1253	182	413	**61679**
HAWAII	1849	2159	6992	98			**11098**
IDAHO	241	3366	98	349			**4054**
ILLINOIS	12446	36630	5370	4345	877	1794	**61462**
INDIANA	7627	27558	1147	3323	196	1872	**41723**
IOWA	980	13392	980	980	980		**17312**
KANSAS	3048	3587	774	1099	372		**8880**
KENTUCKY	3059	13237	3297	535		197	**20325**
LOUISIANA	3618	5136	1078				**9832**
MAINE		19860					**19860**
MARYLAND	15104	35433	4399	7694	244	196	**63070**
MASSACHUSETTS	9139	116721		1267			**127127**
MIAMI	88						**88**
MICHIGAN	20632	61084	14578	6246	343	294	**103177**
MINNESOTA	9486	42536	1609	1351	507	331	**55820**
MISSISSIPPI	4910	8428	2142				**15480**
MISSOURI	10864	24705	6809	2058	392		**44828**
NEBRASKA	751	1499					**2250**
NEVADA	2310	2573	1488	421	490		**7282**
NEW JERSEY	24084	43424	5293	6618	231	691	**80341**
NEW MEXICO	196	98					**294**
NEW YORK	10493	101993	9141	3670	98	86	**125481**
NORTH CAROLINA	5773	6646	4535	819	451		**18224**
OHIO	17958	28239	8797	2090	147	49	**57280**
OKLAHOMA	1313	441	343	735			**2832**
OREGON	4419	7434	58	84	794	5387	**18176**
PENNSYLVANIA	13036	35101	624	98	392	504	**49755**
SOUTH CAROLINA	4410	8491	833				**13734**
TENNESSEE	16744	32722	3875	5398	49		**58788**
TEXAS	75792	131056	22161	36854	1109	2193	**269165**
UTAH	3713	1946	1049	1139	98		**7945**
VERMONT	1232	2146	35		28	42	**3483**
VIRGINIA	5674	4518	882		1225		**12299**
WASHINGTON	23680	44760	2531	2166	1193	441	**74771**
WEST VIRGINIA		49					**49**
WISCONSIN	5534	11914	1211	3528	1027		**23214**
TOTAL	**759,412**	**1,655,048**	**370,826**	**191,719**	**26,919**	**35,525**	**3,039,449**

CALIFORNIA APPLE COMMISSION 2006 - 2007

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	2656	4399					**7055**
ARIZONA	30400	29025	5028	147	1899		**66499**
ARKANSAS		585					**585**
CALIFORNIA	204262	586417	200049	56273	6810	13478	**1067289**
COLORADO	9403	36244	3913	5946	1938	781	**58225**
CONNECTICUT	336	5425					**5761**
DIST. OF COLUMBIA		1071					**1071**
FLORIDA	26197	69204	10275			544	**106220**
GEORGIA	12266	36035	3730	2580		756	**55367**
HAWAII	777	320	2784	49			**3930**
IDAHO	98		49				**147**
ILLINOIS	10096	29889	2889	196	2413	855	**46338**
INDIANA	17419	33295	2286	1617	173	844	**55634**
IOWA	4935	15631	490	1515	3234	10	**25815**
KANSAS	1281	4333	2548	341	735		**9238**
KENTUCKY	11193	16981	126	686		162	**29148**
LOUISIANA	3267	2255	665				**6187**
MAINE	2646	20952		1182			**24780**
MARYLAND	7987	21705	2199	3276		238	**35405**
MASSACHUSETTS	10051	48224	5488	196			**63959**
MICHIGAN	30560	41796	12812	8174			**93342**
MINNESOTA	3475	27835				232	**31542**
MISSISSIPPI	1115	2963	1015				**5093**
MISSOURI	20077	151876	2827	6538			**181318**
NEBRASKA	880	1554	420				**2854**
NEVADA	271	3152	1691	147			**5261**
NEW HAMPSHIRE		21				98	**119**
NEW JERSEY	6124	22393	1029			215	**29761**
NEW MEXICO			740				**740**
NEW YORK	5586	82820	2731	2031			**93168**
NORTH CAROLINA	2622		3871				**6493**
OHIO	22764	60542	5932	5444		83	**94765**
OKLAHOMA	5966	2118					**8084**
OREGON	2513	4398		1735	49	245	**8940**
PENNSYLVANIA	6206	23398	6392		160	394	**36550**
RHODE ISLAND		196					**196**
SOUTH CAROLINA	360	343					**703**
TENNESSEE	6012	24801					**30813**
TEXAS	68366	161211	14463	27939	3645	1470	**277094**
UTAH	6978	6519		1326	294		**15117**
VIRGINIA	5529	5052	730				**11311**
WASHINGTON	37198	27844					**65042**
WEST VIRGINIA		98					**98**
WISCONSIN	4291	4459	147	511			**9408**
TOTAL	**592,163**	**1,617,379**	**297,319**	**127,849**	**21,350**	**20,405**	**2,676,465**

CALIFORNIA APPLE COMMISSION 2007 - 2008

STATE	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
ALABAMA	7007	1877	320				**9204**
ARIZONA	34869	21659	8327	658		57	**65560**
ARKANSAS	2749	1552					**4301**
CALIFORNIA	164591	401910	211817	73568	13359	16357	**881602**
COLORADO	14522	18184	2796	2744	172	371	**38789**
CONNECTICUT		637				637	**1274**
DIST. OF COLUMBIA		196					**196**
FLORIDA	27818	11543	796	1139	245	683	**42224**
GEORGIA	11209	17193	3325			731	**32458**
HAWAII	1352	36	2094	419	14	181	**4096**
IDAHO	1380	518					**1898**
ILLINOIS	6389	22202	2411	3648	2450	2286	**39386**
INDIANA	23194	19032	370	392	444	1176	**44608**
IOWA		8701	3517	980	2576		**15774**
KANSAS	1959		98	3185			**5242**
KENTUCKY	7624	9313					**16937**
LOUISIANA	4312	3129					**7441**
MAINE	2111	23199	770				**26080**
MARYLAND	9861	13381	541	2100	637	280	**26800**
MASSACHUSETTS	10845	29823	147	2401			**43216**
MICHIGAN	20274	15431	5718	196		588	**42207**
MINNESOTA	3509	28185	21	441	2458	619	**35233**
MISSISSIPPI	3045	6026	245				**9316**
MISSOURI	30558	11485	3708	4984			**50735**
MONTANA	0	0	0	0	0	0	**0**
NEBRASKA	4015	2126	63		63		**6267**
NEVADA	2824	5802	1705		230		**10561**
NEW HAMPSHIRE	103	221				424	**748**
NEW JERSEY	3829	15642	2520	294		396	**22681**
NEW MEXICO	1323	3170	640				**5133**
NEW YORK	6096	59925	2675	2450	49	478	**71673**
NORTH CAROLINA	8894	4251	1095				**13145**
OHIO	28481	25165	4282	294		293	**58515**
OKLAHOMA	6035		2400				**8435**
OREGON	2569	629	372		97	963	**4630**
PENNSYLVANIA	8453	15585	476			227	**24741**
RHODE ISLAND	49	490					**539**
SOUTH CAROLINA	3221	670	140				**4031**
TENNESSEE	8584	16207		49			**24840**
TEXAS	61877	107510	12190	32238	1655	980	**216450**
UTAH	10760	4261	1215	147	137		**16520**
VERMONT	0	0	0	0	0	0	**0**
VIRGINIA	6371	3574	1365	539			**11849**
WASHINGTON	5414	6932			98	189	**12633**
WEST VIRGINIA	0	0	0	0	0	0	**0**
WISCONSIN	2909	4760		959			**8628**
WYOMING	4220	2640	570				7430
TOTAL	**565,205**	**944,772**	**278,729**	**133,825**	**24,684**	**27,916**	**1,974,026**

CALIFORNIA APPLE COMMISSION 2008 - 2009

STATE	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
ALABAMA	17805	10038	3914				**31757**
ALASKA	98						**98**
ARIZONA	24454	30298	4107	1078		24	**59961**
ARKANSAS	6475	525					**7000**
CALIFORNIA	274786	673536	177101	93594	4384	25446	**1248847**
COLORADO	12467	17015	3761	3111	844	1260	**38458**
CONNECTICUT	196	2707					**2903**
DIST. OF COLUMBIA	98						**98**
FLORIDA	47269	21400	1081	98	234	3263	**73345**
GEORGIA	15113	23352	4315		147	735	**43662**
HAWAII	1116	677	2709				**4502**
IDAHO	5261	539	294				**6094**
ILLINOIS	21029	34519	3986	343	98	2298	**62273**
INDIANA	15385	18390	2816	1260	84	1957	**39892**
IOWA	588	3094					**3682**
KANSAS	1793	1029	147	245			**3214**
KENTUCKY	11478	12793	1274	666		310	**26521**
LOUISIANA	5026	4782	875				**10683**
MAINE		13174					**13174**
MARYLAND	9307	44072	735	1323	196	49	**55682**
MASSACHUSETTS	13838	74234	1568	2030		247	**91917**
MICHIGAN	35521	67219	8872	9342			**120954**
MINNESOTA	7742	30086	787	1666	28	2464	**42773**
MISSISSIPPI	7868	4646	98				**12612**
MISSOURI	27449	16864	3066	774	98		**48251**
MONTANA		91				49	**140**
NEBRASKA	5605	3525					**9130**
NEVADA	49	3772	196				**4017**
NEW HAMPSHIRE	196	735			221	285	**1437**
NEW JERSEY	11738	46759	441		441	372	**59751**
NEW MEXICO	7450	2742			186		**10378**
NEW YORK	11631	84835	2033	2295	285	758	**101837**
NORTH CAROLINA	21744	8981	2905				**33630**
NORTH DAKOTA		49					**49**
OHIO	33557	34912	4914	6057	147	349	**79936**
OKLAHOMA	10081	3379	935				**14395**
OREGON	8598	9562	2170	735	294	4403	**25762**
PENNSYLVANIA	18972	32776	977	294	441	859	**54319**
SOUTH CAROLINA	4345	4896					**9241**
SOUTH DAKOTA	98						**98**
TENNESSEE	18900	21901		1022			**41823**
TEXAS	98687	130521	11938	27833	245	2759	**271983**
UTAH	14046	11734	3798	2205			**31783**
VIRGINIA	13701	10329	882	147			**25059**
WASHINGTON	20675	26060	2597			471	**49803**
WISCONSIN	11926	5619					**17545**
WYOMING	8355	3960					**12315**
TOTAL	**882,516**	**1,552,127**	**255,292**	**156,118**	**8,373**	**48,358**	**2,902,784**

CALIFORNIA APPLE COMMISSION 2009 - 2010

STATE	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
ALABAMA	22663						**22663**
ARIZONA	26552.6	19541	3420.2	2798		91	**52402.8**
ARKANSAS	13630	3885					**17515**
CALIFORNIA	149145.5	369232	102671.4	56641	9459.9	7272	**694421.8**
COLORADO	8166	4477	6486	1253	955	625	**21962**
CONNECTICUT	588	1813					**2401**
DIST. OF COLUMBIA	196	98					**294**
FLORIDA	41921.5	7412	4711		98	798	**54940.5**
GEORGIA	15769.2	6911	4354		490	196	**27720.2**
HAWAII	963	196	1470				**2629**
IDAHO							**0**
ILLINOIS	30488.3	13201	7799	392	294	1478	**53652.3**
INDIANA	32647	12166	5726	238	245	392	**51414**
IOWA		3318	141	980	14		**4453**
KANSAS	132.3		679	294			**1105.3**
KENTUCKY	12877	5831	98		147	175	**19128**
LOUISIANA	6530	2140	2625				**11295**
MAINE	4140	22842					**26982**
MARYLAND	2598	27267	3758	98	147	536	**34404**
MASSACHUSETTS	3773	38984	2914	3073	2082	21	**50847**
MICHIGAN	20237.2	27456	882	4265			**52840.2**
MINNESOTA	5537	33074	35	490	147	1055	**40338**
MISSISSIPPI	6480	769	49				**7298**
MISSOURI	24122	3360	3555	2591			**33628**
MONTANA	441	294	98		49		**882**
NEBRASKA	10755	2040					**12795**
NEVADA	9400	4428					**13828**
NEW HAMPSHIRE	196	949	147			226	**1518**
NEW JERSEY	9596.3	18128				484	**28208.3**
NEW MEXICO	10685	196	147	98	49		**11175**
NEW YORK	12789.3	61930	4221	2606	2576	327	**84449.3**
NORTH CAROLINA	12041	2212	2115			21	**16389**
NORTH DAKOTA	98						**98**
OHIO	31194	12076	2655	3670		439	**50034**
OKLAHOMA	16354	1505	2520				**20379**
OREGON	2298	5037	1666		98	189	**9288**
PENNSYLVANIA	21725.05	30759	4277.7		667.1	963	**58391.85**
SOUTH CAROLINA	8970	1054					**10024**
SOUTH DAKOTA							**0**
TENNESSEE	23015.4	8267.9	98				**31381.3**
TEXAS	90441.18	61265	7539	22239	245	1421	**183150.18**
UTAH	24394	6667	3724	224			**35009**
VIRGINIA	9983.5	4465	398.3				**14846.8**
WASHINGTON	14969	6605	5334			105	**27013**
WISCONSIN	9708	3820	2800	147	182		**16657**
WYOMING	15253	3504					**18757**
TOTAL	**763,463**	**839,175**	**189,114**	**102,097**	**17,945**	**16,814**	**1,928,608**

CALIFORNIA APPLE COMMISSION - UNITED STATES 2010 - 2011

STATE	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
ALABAMA	14342	49					**14391**
ARIZONA	59031	42189	714	490	1593	269	**104286**
ARKANSAS	3960	3700					**7660**
CALIFORNIA	336880.4	360229.7	258476.4	84676.7	16105.2	27485.53	**1083854**
COLORADO	10817.8	6159	2093	1909	49	1225	**22252.8**
CONNECTICUT		2940					**2940**
DIST. OF COLUMBIA	854	784	98				**1736**
FLORIDA	25780.6	13003.1	4368	240.1	128.1	499	**44018.9**
GEORGIA	20929.8	15512	4246	1078		927.1	**42692.9**
HAWAII	987	123	441				**1551**
ILLINOIS	40796.3	25316.8	4796			538.5	**71447.6**
INDIANA	16546	9054	4375		98	1939	**32012**
IOWA	2072	2058			49		**4179**
KANSAS	98	98		1073			**1269**
KENTUCKY	14323	1074	147	5880	514		**21938**
LOUISIANA	4234	5499	1995				**11728**
MAINE	1738	17983					**19721**
MARYLAND	3647	23335	1239	2177		1470	**31868**
MASSACHUSETTS	4879	56419	2205	5376	245		**69124**
MICHIGAN	5150	14247	6037	652	245		**26331**
MINNESOTA	9996.3	49460	245	2695	326	441	**63163.3**
MISSISSIPPI	6039						**6039**
MISSOURI	15068.5	10924.5	2660	1470	98		**30221**
MONTANA				49			**49**
NEBRASKA	4175						**4175**
NEVADA	18566	24762	49				**43377**
NEW HAMPSHIRE	441	147			147	288	**1023**
NEW JERSEY	7135	23917	985	273.7		1331	**33641.7**
NEW MEXICO	11296	2798	244		98		**14436**
NEW YORK	7020.15	68482.8	1905.15	1118	98		**78624.1**
NORTH CAROLINA	12746	6768	4011	50	529.2	1	**24105.2**
NORTH DAKOTA	98						**98**
OHIO	13440	5911	5295	5864		190	**30700**
OKLAHOMA	12915.2	8098	1934.2	196			**23143.4**
OREGON	7470	947	2176	486	87	273	**11439**
PENNSYLVANIA	24328.2	27605	4684	1078	539	378	**58612.2**
SOUTH CAROLINA	6650	7806					**14456**
TENNESSEE	13569.3	6692.2	1862	1862			**23985.5**
TEXAS	102382.7	74606.2	10105.5	24338	1835.4	1883	**215150.8**
UTAH	22768	147	116	490	28		**23549**
VIRGINIA	6860	4508		637			**12005**
WASHINGTON	9543	13650	4620			196	**28009**
WEST VIRGINIA				3			**3**
WISCONSIN	9943	5528	1610	539			**17620**
WYOMING	8590	5637	2240				**16467**
TOTAL	**898,106**	**948,167**	**335,972**	**144,701**	**22,812**	**39,334**	**2,389,092**

CALIFORNIA APPLE COMMISSION - UNITED STATES 2011 - 2012

STATE	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
ALABAMA	14602.2	14319		147			**29068.2**
ARIZONA	33583.3	27018	3405	5160		1653	**70819.3**
ARKANSAS	9425						**9425**
CALIFORNIA	187132.7	251077.4	102186.3	48385.15	2600.5	60198	**651580.05**
COLORADO	18294.3	15684.9	3009	1596	303	1429	**40316.2**
CONNECTICUT	3388	1568	98				**5054**
DIST. OF COLUMBIA	196	196				686	**1078**
FLORIDA	35384.2	30768.4	2588		21	3174	**71935.6**
GEORGIA	31182.5	17718	7505	2450		3058	**61913.5**
HAWAII	294	98	343				**735**
IDAHO	133	539					**672**
ILLINOIS	41511.1	35830.9	4893.1	3920	245	5609	**92009.1**
INDIANA	34460.6	31970	3103		210	2925	**72668.6**
IOWA	483.1	5497	32		234		**6246.1**
KANSAS	2604.6	4440	198.7	588		1675	**9506.3**
KENTUCKY	14240	23990	882		147	1397	**40656**
LOUISIANA	13133	5045	3220				**21398**
MAINE	1631	11870					**13501**
MARYLAND	6451	17761.3	21655	7028		3155	**56050.3**
MASSACHUSETTS	4949	37752.4	4655	6909	156	8272	**62693.4**
MICHIGAN	26632.6	21455.3	7670	196	420	4953	**61326.9**
MINNESOTA	11598.3	54720.5	49	2429	1742.3	19808	**90347.1**
MISSISSIPPI	3705	3045					**6750**
MISSOURI	27841.7	16293.3	5754	1637		3466	**54992**
MONTANA	245	1077					**1322**
NEBRASKA	7605	7163.1		168			**14936.1**
NEVADA	7319	7323	245			1134	**16021**
NEW HAMPSHIRE	350	420			21	290	**1081**
NEW JERSEY	6344	18777	196		14	812	**26143**
NEW MEXICO	11473	5948	49				**17470**
NEW YORK	8182.2	36120.1	2128	3393		5186	**55009.3**
NORTH CAROLINA	8000	24677.2	2974	416.8	63	273	**36404**
NORTH DAKOTA		28		40		147	**215**
OHIO	42361.3	24357.1	7017	539	98	1428	**75800.4**
OKLAHOMA	13444.7	12475.2	1533		145	49	**27646.9**
OREGON	2685.7	4004.9	196			962	**7848.6**
PENNSYLVANIA	19164.7	33233	2856	7894	258	3615	**67020.7**
RHODE ISLAND		147					**147**
SOUTH CAROLINA	1160	10472				294	**11926**
TENNESSEE	15619.7	12703.5		1746		2058	**32127.2**
TEXAS	91224.8	93039.95	6795	19445	441	7071	**218016.75**
UTAH	27451.7	13053	4420	735		98	**45757.7**
VERMONT	196	49					**245**
VIRGINIA	8295	11546	686			1134	**21661**
WASHINGTON	18581	28204	6569		49	7093	**60496**
WISCONSIN	8934	10636	665	196	33	637	**21101**
WYOMING	18420	5235	1820				**25475**
TOTAL	**839,913**	**989,347**	**209,396**	**115,018**	**7,201**	**153,739**	**2,314,612.30**

CALIFORNIA APPLE COMMISSION - UNITED STATES 2012 - 2013

STATE	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
ALABAMA	7357	9864	186				**17407**
ARIZONA	17341	16655	4374	1294	21		**39685**
ARKANSAS	3998						**3998**
CALIFORNIA	219877	297090	94785	45606	5645	15727	**678730**
COLORADO	12799	8610	2401	266	125	1674	**25875**
CONNECTICUT	343	539					**882**
FLORIDA	32641	16582	4880	29		98	**54230**
GEORGIA	19698	16398	8218	2940	147		**47401**
HAWAII	1076	1027	1244				**3347**
IDAHO	490						**490**
ILLINOIS	27676	14968	1581	9124	411	1238	**54998**
INDIANA	10106	6154	3357		98	671	**20386**
IOWA	952	3846	98	294	1019		**6209**
KANSAS	2500	819		294			**3613**
KENTUCKY	7181	24046	260		196	98	**31781**
LOUISIANA	2413	1664	4164				**8241**
MAINE	854	6514					**7368**
MARYLAND	3528	12831	2037	1390	14	532	**20332**
MASSACHUSETTS	13181	20379	3087	1420	392	21	**38480**
MICHIGAN	20278	21915	18758		21		**60972**
MINNESOTA	2010	43745	693	581	695	2049	**49773**
MISSISSIPPI	6829						**6829**
MISSOURI	23265	19175	3049				**45489**
MONTANA	196			182			**378**
NEBRASKA	1708						**1708**
NEVADA	3450	10680	296				**14426**
NEW HAMPSHIRE	147	245	52			1459	**1903**
NEW JERSEY	603	10569	472			1299	**12943**
NEW MEXICO	3899	147					**4046**
NEW YORK	10400	28939	1205	1716	56	42	**42358**
NORTH CAROLINA	2399	4811	1313				**8523**
NORTH DAKOTA		209					**209**
OHIO	22938	10808	2874	1743	49	980	**39392**
OKLAHOMA	9288	49	455				**9792**
OREGON	3309	2891		686		137	**7023**
PENNSYLVANIA	14849	27839	1889	4471	35	1310	**50393**
SOUTH CAROLINA	2764	3136					**5900**
TENNESSEE	9751	7925		490			**18166**
TEXAS	81150	84894	9104	19239	978	2551	**197916**
UTAH	11847	777	399	1540	35		**14598**
VERMONT	49						**49**
VIRGINIA	1894	2296	377				**4567**
WASHINGTON	9238	14858	134	1070	147		**25447**
WISCONSIN	7845	294	287	91	444		**8961**
WYOMING	5178		175				**5353**
TOTAL	**639,296**	**754,189**	**172,204**	**94,466**	**10,528**	**29,886**	**1,700,568**

CALIFORNIA'S TOP 5 STATES

	1997 - 1998	
1	California	1,473,883
2	New York	272,830
3	Texas	199,931
4	Illinois	149,680
5	Florida	128,716

	1998 - 1999	
1	California	1,239,929
2	New York	157,353
3	Texas	140,908
4	Massachus	104,002
5	Illinois	91,691

	1999 - 2000	
1	California	1,579,999
2	New York	278,022
3	Massachus	189,056
4	Texas	178,489
5	Florida	155,478

	2000 - 2001	
1	California	1,282,349
2	New York	239,647
3	Texas	193,518
4	Arizona	98,490
5	Florida	94,463

	2001 - 2002	
1	California	1,146,587
2	New York	473,316
3	Texas	212,378
4	Massachus	105,896
5	Florida	96,877

	2002 - 2003	
1	California	1,348,951
2	Texas	279,028
3	Massachus	126,021
4	New York	191,624
5	Illinois	141,671

	2003 - 2004	
1	California	1,409,491
2	Texas	328,190
3	New York	212,095
4	Florida	153,483
5	Illinois	130,305

	2004 - 2005	
1	California	1,385,719
2	Texas	289,084
3	New York	172,145
4	Michigan	113,914
5	Florida	104,664

	2005 - 2006	
1	California	1,281,242
2	Texas	269,165
3	Massachuse	127,127
4	New York	125,481
5	Michigan	103,177

	2006 - 2007	
1	California	1,067,289
2	Texas	277,094
3	Missouri	181,318
4	Florida	106,220
5	Ohio	94,765

	2007 - 2008	
1	California	881,602
2	Texas	216,450
3	New York	71,673
4	Arizona	65,570
5	Ohio	58,515

	2008 - 2009	
1	California	1,071,112
2	Texas	253,561
3	Michigan	109,280
4	New York	87,951
5	Massachuse	75,794

	2009 - 2010	
1	California	694,422
2	Texas	183,150
3	New York	84,449
4	Pennsylvania	58,392
5	Florida	54,940

	2010 - 2011	
1	California	1,083,854
2	Texas	215,150
3	Arizona	104,286
4	New York	78,624
5	Illinois	71,447

	2011 - 2012	
1	California	651,580
2	Texas	218,016
3	Illinois	92,009
4	Minnesota	90,347
5	Ohio	75,800

	2012 - 2013	
1	California	678,730
2	Texas	197,916
3	Michigan	60,972
4	Illinois	54,998
5	Florida	54,230

EXPORT TOTALS FOR 2006 - 2007

COUNTRY	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
CANADA	119,581	182,319		147		345	**302,392**
CHINA		980					**980**
COLOMBIA		8,793					**8,793**
COSTA RICA		2,251		980			**3,231**
ECUADOR		6,412					**6,412**
EL SALVADOR	840	2,058					**2,898**
HONDURAS		413					**413**
INDIA		4,038					**4,038**
INDONESIA		3,500					**3,500**
MALAYSIA		73,409	9			217	**73,635**
MEXICO	21,244	34,352	2,229				**57,825**
NICARAGUA		380					**380**
PANAMA	686	3,990		980			**5,656**
PERU		1,960					**1,960**
PHILIPPINES		2,938					**2,938**
PUERTO RICO	24	221					**245**
SINGAPORE	840	33,844					**34,684**
SRI LANKA		10,216					**10,216**
TAIWAN	3,267	8,826	95,505				**107,598**
THAILAND	2,520	3,185					**5,705**
UNITED KINGDOM				57,531			**57,531**
VENEZUELA		1,568					**1,568**
TOTAL	**149,002**	**385,653**	**97,743**	**59,638**	**0**	**562**	**692,598**

EXPORT TOTALS FOR 2007 - 2008

COUNTRY	GALA	GRANNY SMITH	FUJI	PINK LADY	BRAEBURN	OTHER	TOTAL
CANADA	121,382	115,132	199	343	312	804	**238,172**
COLOMBIA		1,911					**1,911**
ECUADOR		1,848					**1,848**
GUATEMALA	533	846					**1,379**
HONG KONG		6,420					**6,420**
INDIA		5,823	980				**6,803**
INDONESIA		1,800					**1,800**
JAMAICA	490						**490**
KUWAIT		1,911					**1,911**
MALAYSIA		56,378	1,555			84	**58,017**
MEXICO	16,737	1,494					**18,231**
PANAMA	2,131	3,969					**6,100**
PERU		980					**980**
PUERTO RICO	49						**49**
SAUDI ARABIA	4,742						**4,742**
SINGAPORE		21,367	524				**21,891**
SRI LANKA		1,911					**1,911**
TAIWAN			30,786				**30,786**
THAILAND	1,462	1,154	756				**3,372**
UNITED KINGDOM				31,298			**31,298**
TOTAL	**147,526**	**222,944**	**34,800**	**31,641**	**312**	**888**	**438,111**

EXPORT TOTALS FOR SEASON 2008 - 2009

COUNTRY	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
CANADA	93,120	130,021	8,858	147		906	**233,052**
COLOMBIA		931					**931**
COSTA RICA		441					**441**
ECUADOR		4,200					**4,200**
HONG KONG		1,928					**1,928**
INDIA		3,920					**3,920**
INDONESIA		11,260					**11,260**
JAMAICA	392						**392**
MALAYSIA		129,263	196				**129,459**
MEXICO	58,409	38,038	3,773				**100,220**
NEW ZEALAND		5,128					**5,128**
PANAMA	994	6,603	784				**8,381**
SINGAPORE		44,532					**44,532**
SRI LANKA		6,878					**6,878**
TAHITI	30						**30**
TAIWAN		1,927	68,341				**70,268**
THAILAND		2,860					**2,860**
UNITED ARAB EMIRATES		3,528					**3,528**
UNITED KINGDOM				16,443			**16,443**
TOTAL	**152,945**	**391,458**	**81,952**	**16,590**		**906**	**643,851**

EXPORT TOTALS FOR SEASON 2009 - 2010

COUNTRY	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
CANADA	73,849	54,643	1,127	392		119	130,130
COLOMBIA		1,960					1,960
COSTA RICA	900	98					998
ECUADOR		1,680					1,680
EL SALVADOR	2,700						2,700
INDIA		1,078					1,078
INDONESIA		13,173					13,173
JAMAICA	45						45
MALAYSIA		38,509					38,509
MEXICO	13,197	2,058					15,255
PANAMA	490	1,078	267				1,835
PERU		2,254					2,254
PHILLIPPINES		1,917					1,917
SAUDI ARABIA		2,156					2,156
SINGAPORE	840	17,234					18,074
TAIWAN	5,840	6,589	59,033				71,462
THAILAND	900	4,760					5,660
UNITED ARAB EMIRATES		14,065					14,065
UNITED KINGDOM	1,820						1,820
VIETNAM		980					980
TOTAL	**100,581**	**164,232**	**60,427**	**392**		**119**	**325,751**

EXPORT TOTALS 2010 - 2011

COUNTRY	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
CANADA	51,241	63,779	98	1,617		147	116,882
COLOMBIA		980					980
ECUADOR		294					294
HONG KONG		3,038					3,038
INDIA		245					245
INDONESIA		14,592					14,592
MALAYSIA		13,643					13,643
MEXICO	17,339	17,297					34,636
NEW ZEALAND		980					980
PERU		2,900					2,900
PHILLIPPINES		3,871					3,871
SINGAPORE		4,580					4,580
TAIWAN	2,664	2,590	31,700				36,954
THAILAND		3,890					3,890
VIETNAM		4,900					4,900
TOTAL	71,244	137,579	31,798	1,617		147	242,385

EXPORT TOTALS 2011 - 2012

COUNTRY	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
CANADA	161,846	49,674	2,450	2,143		16,675	232,788
COLOMBIA		980					980
ECUADOR		5,965					5,965
HONG KONG		965					965
INDONESIA		1,940					1,940
MALAYSIA		30,818					30,818
MEXICO	9,968	8,799		2,058			20,825
PANAMA		7791					7,791
PERU		2,940					2,940
PHILLIPPINES		2,910					2,910
SRI LANKA		5,880					5,880
TAIWAN			15,629				15,629
THAILAND		5,769					5,769
TOTAL	171,814	124,431	18,079	4,201	0	16,675	335,200

EXPORT TOTALS 2012 - 2013

COUNTRY	GALA	GRANNY SMITH	FUJI	CRIPPS PINK	BRAEBURN	OTHER	TOTAL
CANADA	147,268	57,066	9,635	980	147	931	216,027
COLOMBIA		2,875					2,875
COSTA RICA	911						911
EL SALVADOR	931						931
HONG KONG		1,029					1,029
INDONESIA		2,940					2,940
MALAYSIA		31,713					31,713
MEXICO	13,425	26,278					39,703
PANAMA		1,617					1,617
PERU		3,087					3,087
PHILLIPPINES		2,903					2,903
PUERTO RICO		42					42
SINGAPORE		5,419					5,419
SRI LANKA		900					900
TAIWAN		5,152	31,384				36,536
THAILAND		9,775					9,775
VIETNAM		980					980
TOTAL	162,535	151,776	41,019	980	147	931	357,388