# 2018-2019
# CALIFORNIA APPLE COMMISSION
# ANNUAL REPORT

2018-2019

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CALIFORNIA APPLE COMMISSION

## OFFICE

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# MESSAGE FROM THE EXECUTIVE DIRECTOR

Todd W. Sanders
Executive Director

The 2018-2019 season proved to be another successful year for the California apple industry. To start, the Commission underwent and passed its referendum review. During the hearing, there was overwhelming support for the continuation of the Commission. Based on sufficient evidence, and the support the Commission received during the hearing, the California Department of Food and Agriculture (CDFA) approved the continuation of the Commission for another five years.

In other successes, the litigation that the California Apple Commission was embroiled in is officially finalized with the litigant removing their appeal. This is an important victory for both the Commission and the California apple industry as we can now move forward with other business. The Commission would like to thank the KAHN, SOARES & CONWAY, LLP legal team for all their work over the past 19 years on behalf of the Commission.

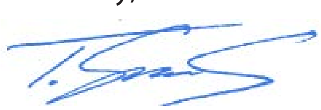
In addition to the California Apple Commission overseeing the California Blueberry Association, California Blueberry Commission, and the California Olive Committee, the Commission now manages the Olive Growers Council of California. This compliments the Commission's philosophy of managing other commodities to share resources and capabilities.

The Commission continues to focus on keeping export markets open for California through their oversight of the Taiwan and Mexico programs, to name a few. Thanks to the Commission's efforts, the Mexico oversight program has been reduced. As a result, 2019 will be the last year the inspector will visit California until 2022, and they will only return every three years thereafter. This is an enormous success, as the Commission has been working to reduce inspection visits for 15 years. Moving forward, APHIS will handle inspections for Mexico, reducing costs and saving the grower and packer time and money.

Additionally, the Commission continues to look into other research opportunities. For example, the Commission has partnered with Dr. Gennaro Fazio with the United States Department of Agriculture - Agricultural Research Service (USDA - ARS), at no cost to the Commission, regarding Geneva Rootstock implementation. Furthermore, the Commission is expanding its research for organically grown apples, as the organic section within the industry continues to grow.

On behalf of the California Apple Commission, I am pleased to present to you the 2018-2019 annual report. As always, thank you for your continued support of the California Apple Commission, and we look forward to serving you in the next year.

Sincerely,



Todd W. Sanders
Executive Director

# CHAIRMAN'S CORNER

Jeff Colombini
Chairman

As my first year serving as the California Apple Commission's Chairman comes to a close, I am pleased to share with you some of the many accomplishments that the California apple industry has experienced during the 2018 - 2019 year. The Commission was approved by the California Department of Food and Agriculture (CDFA) to operate for another five years. One of the greatest accomplishments this year occurred when the California Court of Appeals ruled in the Commissions' favor after nearly two decades of litigation.

The Commission continues to act on behalf of the growers and handlers. With California growers and handlers working together through the Commission, we have made some great accomplishments. For example, the Commission has reduced the Mexico oversight program from annual inspections, to the inspector coming to California every three years, and instead allowing AHPIS to handle Mexico inspections.

Apple research remains an important effort of the Commission's. This year, the Commission partnered with the United States Department of Agriculture – Agricultural Research Service's (USDA- ASR) Dr. Gennaro Fazio in regard to Geneva Rootstock testing at no cost to the Commission, ultimately saving the growers and handlers money. Furthermore, as the organic sector of the apple industry grows, the Commission continues to broaden their research for organically grown apples.

As our industry continues to grow, it is important to utilize the resources that the Commission provides. Please reach out to the Commission as we go into the 2019-2020 season. Thank you for allowing me to serve as your Chairman, and I look forward to helping advance the California apple industry.

Sincerely,

Jeff Colombini
Chairman

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# BOARD OF DIRECTORS

| DISTRICT 1 | DISTRICT 2 | DISTRICT 3 |
|---|---|---|
| **Producer Member**<br>David Rider<br>Bruce Rider & Sons<br>Term: 7/2016-6/2020 | **Producer Member**<br>Chris Britton<br>BK Partners<br>Term: 7/2018-6/2022 | **Producer Member**<br>Jeff Colombini<br>Lodi Farming<br>Term: 7/2017-6/2021 |
| **Producer Member**<br>Lance Shebelut<br>Trinity Fruit Sales<br>Term: 7/2016-6/2020 | **Producer Member**<br>Virginia Hemly Chhabra<br>Greene and Hemly<br>Term: 7/2018-6/2022 | **Producer Member**<br>Steve Chinchiolo<br>Riverbend Orchards<br>Term: 7/2018-6/2022 |
| **Handler Member**<br>Bill Denevan<br>Viva Tierra<br>Term: 7/2017-6/2021 | **Handler Member**<br>VACANT<br>Term: 7/2017-6/2021 | **Handler Member**<br>Tim Sambado<br>Prima Frutta<br>Term: 7/2017-6/2021 |
| **Alternate Member**<br>VACANT<br>Term: 7/2018-6/2019 | **Alternate Member**<br>Doug Hemly<br>Greene and Hemly<br>Term: 7/2018-6/2019 | **Alternate Member**<br>VACANT<br>Term: 7/2018-6/2022 |
| | **Public Member**<br>Dr. Steve Blizzard<br>Term: 7/2017-6/2021 | |

# DISTRICT MAP

# CALIFORNIA APPLE ACREAGE TOTALS

| COUNTY | |
|---|---|
| BUTTE | 40.00 |
| CALAVERAS | 10.00 |
| COLUSA | 10.50 |
| CONTRA COSTA | <50.00 |
| EL DORADO AND ALPINE | 852.00 |
| FRESNO | 440.00 |
| GLENN | 1.00 |
| INYO AND MONO | 4.50 |
| KERN | 732.00 |
| KINGS | 3.00 |
| LAKE | 5.00 |
| LOS ANGELES | 10.00 |
| MADERA | 115.10 |
| MARIPOSA | 10.00 |
| MENDOCINO | 40.00 |
| MERCED | 1.00 |
| MONTEREY | 66.58 |
| NAPA | 3.59 |
| NEVADA | 32.00 |
| PLACER | 20.50 |
| PLUMAS AND SIERRA | 2.00 |
| RIVERSIDE | 28.00 |
| SACRAMENTO | 567.00 |
| SAN BENITO | 387.55 |
| SAN BERNARDINO | 305.00 |
| SAN DIEGO | 214.00 |
| SAN JOAQUIN | 2,330.00 |
| SAN LUIS OBISPO | 228.71 |
| SAN MATEO | 14.90 |
| SANTA BARBARA | 210.00 |
| SANTA CRUZ | 2,027.00 |
| SHASTA | 17.00 |
| SISKIYOU | 26.00 |
| SONOMA | 2,166.00 |
| STANISLAUS | 492.10 |
| SUTTER | 8.00 |
| TEHAMA | 35.50 |
| TULARE | 86.00 |
| TUOLUMNE | 9.50 |
| VENTURA | 486.00 |
| YOLO | 132.50 |
| YUBA | 10.00 |
| **TOTAL:** | **12,229.53** |

# STATEMENT FOR ACTIVITES

## FISCAL YEAR ENDED JUNE 30, 2018

**ASSETS**

| | |
|---|---|
| • CASH | $114,992 |
| • ACCOUNTS RECEIVABLE | $11,019 |
| • PREPAID EXPENSES | $1,750 |
| • RESTRICTED CASH DUE TO PENDING LAWSUIT | $1,731,060 |
| • PROPERTY AND EQUIPMENT NET OF ACCUMULATED DEPRECIATION OF $14,280 IN 2018 AND $15,044 IN 2018 | $4,915 |
| **TOTAL ASSETS** | **$1,863,736** |

**LIABILITIES**

| | |
|---|---|
| • ACCOUNTS PAYABLE | $54,593 |
| • ACCRUED COMPENSATED ABSENCES | $13,326 |
| **TOTAL CURRENT LIABILITIES** | **$67,919** |

**NET ASSETS**

| | |
|---|---|
| • RESTRICTED | |
| - ESCROW ACCOUNT | $1,731,060 |
| • UNRESTRICTED | $64,757 |
| **NET ASSETS** | **$1,795,817** |

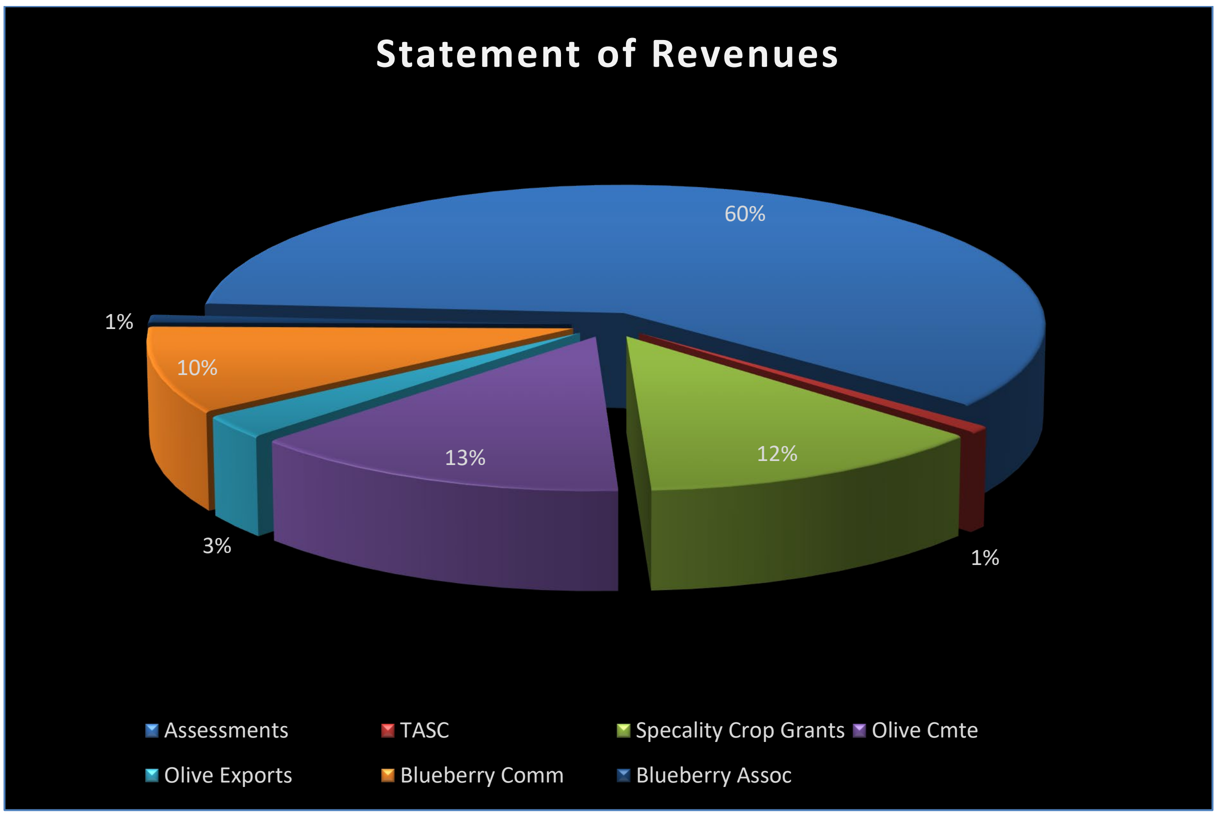
| | |
|---|---|
| **TOTAL LIABILITIES AND NET ASSETS** | **$1,863,736** |

# STATEMENT OF REVENUES

## REVENUES

| | |
|---|---|
| • ASSESSMENTS | $396,264* |
| • GRANT INCOME – TASC | $5,050 |
| • SPECIALTY CROP BLOCK GRANT | $82,951 |
| • COMMODITY MANAGEMENT FEES | $178,500 |

**TOTAL REVENUES** **$662,765**



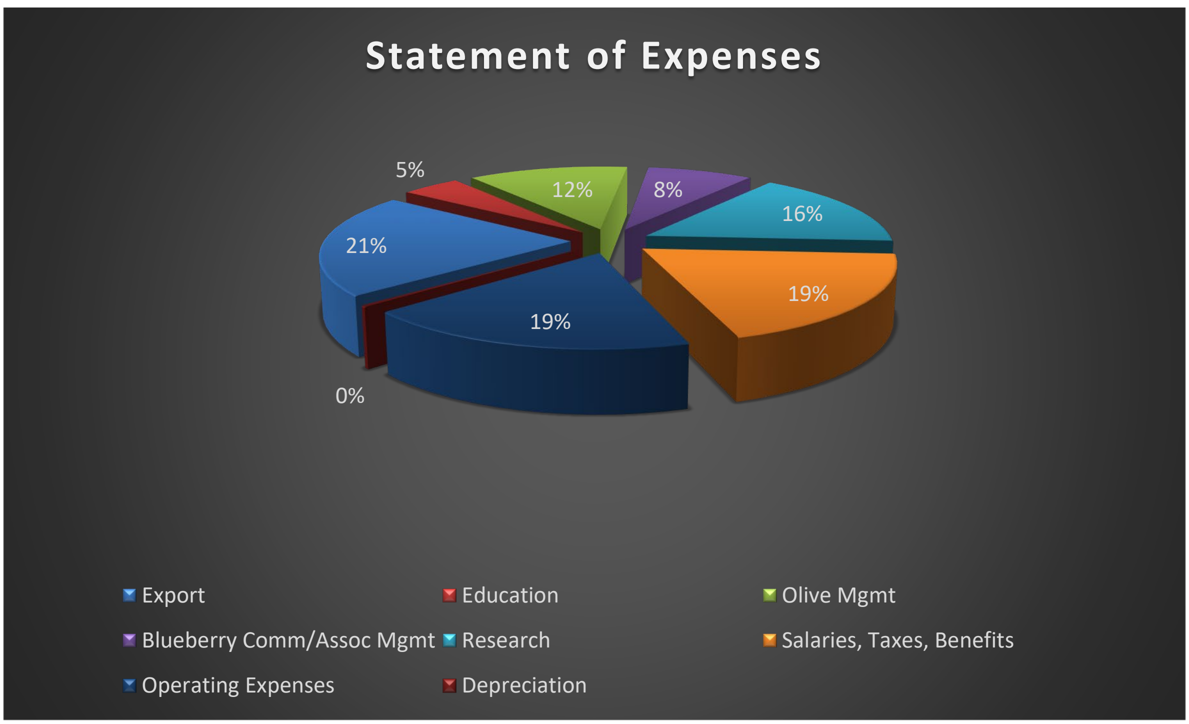

*Includes restricted revenues received pending current lawsuit. Restricted funds shall not be used in operating budget and are stored in a separate escrow account. These funds may not be released until lawsuit is finalized.

# STATEMENT OF EXPENSES

## EXPENSES

| | |
|---|---|
| • EXPORT/MARKET DEVELOPMENT | $136,324 |
| • EDUCATION | $28,749 |
| • OLIVE MANAGEMENT | $78,443 |
| • BLUEBERRY MANAGEMENT | $51,849 |
| • RESEARCH | $102,104 |
| • SALARIES, PAYROLL TAXES, BENEFITS | $121,829 |
| • OPERATING EXPENSES | $118,494 |
| • DEPRECIATION | $2,016 |

**TOTAL EXPENSES** **$639,828**




**CHANGES IN NET POSITION** **$23,630**

**NET POSITION, BEGINNING OF YEAR** **$1,772,187**

**NET POSITION, END OF YEAR** **$1,795,817**

# CALIFORNIA APPLE RESEARCH PROJECTS

# 2018-2019 RESEARCH SUMMARY

In 2018-2019, the California Apple Commission focused on four areas of research, three of which were continuations of prior research. Each of these research topics will continue to be areas of focus for the future as well.

In summary, our current projects are as follows:

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) Postharvest Quality and Physiology of 'Gala', 'Granny Smith,' and 'Fuji' Apples Subjected to Phytosanitary Irradiation. - Dr. Anuradha Prakash

3) Study on Mechanical Mass Harvesting of Cling Peaches[1] - Dr. Stavros Vougioukas

4) Apple Rootstock Breeding Program Field Trials[2]- Dr. Gennaro Fazio

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[1]The CAC has partnered with the Cling Peach board for this research project. The research includes apples and is applicable to our industry as well.

[2]The CAC has partnered with the Cornell University/USDA-Agricultural Research Service Apple Rootstock Breeding Program to conduct field trials of Geneva rootstocks in California in the spring of 2020.

## Annual Report – 2018-19

*Prepared for the California Apple commission*

| | |
|---|---|
| Project Title: | Evaluation of new biological controls for management of fire blight of apples caused by *Erwinia amylovora* and evaluation of new natural products as organic postharvest fungicides for pome fruits |
| Project Leader: | Dr. J. E. Adaskaveg, Department of Plant Pathology and Microbiology, University of California, Riverside CA 92521. |
| Cooperators: | D. Thompson, D. Cary, and H. Förster |


**SUMMARY**

**Fire blight management**

1. Antibiotic and copper resistance surveys for populations of *Erwinia amylovora* in California pear growing areas were continued in 2018.
   a. Kasugamycin: All 70 strains from 13 orchard locations in Sacramento and Lake Co. were sensitive.
   b. Streptomycin: Resistance was detected in all but one location. Forty-two of the resistant strains had plasmid-based moderate resistance (MIC <20 ppm) and 19 strains displayed high resistance that most likely was chromosomal-based. Thus, populations of *E. amylovora* re-adjust rapidly to selection pressure (i.e., bactericide applications). Streptomycin should be used strategically, and these findings stress the importance of resistance management with mixtures or rotations and that new alternatives need to be developed.
   c. Oxytetracycline: For the first time, high levels of resistance with growth at >40 ppm were detected at two locations. These resistant strains were also highly resistant to streptomycin. In the location with the highest incidence of $Oxy^R$, nine applications of the antibiotic were applied between 2017 and 2018. Oxytetracycline resistance in *E. amylovora* has never been reported previously at this level, and this finding is a serious concern. Currently, it is not known if these resistant strains are competitively fit and will persist in the absence of selection pressure.
   d. Copper: Moderate copper resistance was present in strains of *E. amylovora*. Growth was similar to the control using 20 ppm MCE and was reduced at 30 ppm MCE on nutrient agar. Spontaneous mutants growing at high concentrations of copper were also observed. Management failures with the use of copper under high disease pressure have been attributed to highly favorable environments, low rates of copper registered, moderate copper resistance, and spontaneous mutants with high copper resistance.
   e. In 30-min direct exposures of *E. amylovora* suspensions to the food preservatives nisin or ε-poly-L-lysine, the toxicity of both compounds was significantly increased with the addition of ethylenediaminetetraacetic acid (EDTA).
2. Field trials on the management of fire blight were conducted under high disease pressure on cvs. Granny Smith and Fuji apple, as well as under low disease pressure on Bartlett pear.
   a. On Granny Smith apple, Blossom Protect with the newly formulated buffer additive was the most effective treatment. The rotation treatment of Badge, Badge + ProPhyt, followed by two applications of Blossom Protect, however, was somewhat less effective. Statistically similarly effective treatments to Blossom Protect were Kasumin + FireWall, Kasumin + ε-poly-L-lysine + zinc oxide, as well as Kasumin 2L and Kasumin 4L by themselves. Nisin and ε-poly-L-lysine by themselves were only moderately effective, and the addition of EDTA and zinc oxide to nisin or of Dart (28.3% capric and 41.7% caprylic acids) to ε-poly-L-lysine resulted in numerical but not statistical increases in efficacy.
   b. On Fuji apple, Kasumin 2L and 4L, and FireLine + zinc oxide + Dart provided the highest efficacy among treatments evaluated. Among treatments containing the preservatives nisin or ε-poly-L-lysine, ε-poly-L-lysine + zinc oxide + EDTA was most effective.
   c. In small-scale studies, two new experimental biocontrol agents were not effective in reducing fire blight.
   d. Kasumin is currently considered a conventional treatment, however, efforts are underway to obtain an organic registration. The compound is a natural substance that is commercially produced by fermentation. In contrast to streptomycin and oxytetracycline, it has very minimal or no usage in human medicine.

**Postharvest decay control**

1. In laboratory studies on control of blue mold and gray mold of apple, the high-solubility formulation of natamycin was numerically more effective than the BioSpectra formulation. Natamycin again was not effective in reducing blue mold of pears, and there were differences in efficacy also among sources of apple fruit that may be related to the fruit age (time of storage after harvest).
2. In an experimental packingline study using in-line drench applications, BioSpectra significantly reduced blue mold and gray mold of Granny Smith apple, but a treatment with 300 ppm Scholar was significantly more effective.
3. The efficacy of natamycin needs to be improved for apples and other pome fruits. Although efficacy of Scholar or Academy is not improved when BioSpectra is added in mixture treatments, natamycin represents a resistance management strategy. Resistance to natamycin has not been reported previously to any *Penicillium* species, although the compound has been registered for food uses for over 20 years.

**INTRODUCTION**

***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. Current control programs are based on protective schedules because available compounds are contact treatments and are not systemic except for the antibiotic streptomycin. Registered treatments include copper products, antibiotics, as well as natural products and biocontrol agents. Conventional copper compounds are only effective when disease severity is low to moderate. They may cause fruit russeting and therefore, labeled rates are at low amounts of metallic copper equivalent (MCE) that are at the limit of effectiveness. New re-formulated copper products that can be used at reduced MCE rates and that cause less phytotoxicity are available. Some products are OMRI-approved including Badge X2, CS-2005, and Cueva. Because only few treatments are permitted for organic apple production, research on OMRI-approved coppers needs to be continued, and some were included in our 2018 field studies. In our surveys, however, we detected low to moderate levels of copper insensitivity in pathogen populations.

The antibiotics streptomycin and oxytetracycline can only be used in conventional pome fruit production. The incidence of resistance to streptomycin in California orchards has been fluctuating from very high to low in our surveys between 2006 and 2017. Reduced sensitivity to oxytetracycline has only been found sporadically, and these isolates did not persist. Kasugamycin (Kasumin) is now registered in California. Resistance to kasugamycin in *E. amylovora* has not been found to date. Efforts are ongoing to differentiate kasugamycin from other bactericides and allow certification as an organic treatment by the National Organic Standards Board and OMRI.

The biocontrol treatments Blight Ban A506 (*Pseudomonas fluorescens* strain A506) and Bloomtime Biological (*Pantoea agglomerans* strain E325), and the fermentation product of *Bacillus subtilis* Serenade (strain QST 713) have been inconsistent over the years in their performance in our trials and were most effective under low inoculum levels and less favorable micro-environments. The biocontrol Blossom Protect (*Aureobasidium pullulans*) has been very effective under less to moderately favorable disease conditions, and it is one of the most consistent biologicals that we have evaluated. Biocontrols are most effective when they are actively growing on the plant. A new buffer additive for Blossom Protect that was developed to increase growth of the biocontrol agent became available in 2019 and was included in our field studies. We are also evaluating other bactericide alternatives such as the natural fermentation compounds lactic acid, ε-poly-L-lysine, and nisin that have known anti-bacterial activity and are used as food preservatives. They potentially could qualify for organic production. Our initial evaluations with these compounds showed high toxicity in lab studies, but only moderate activity in the field. Therefore, we continue to try to improve their efficacy by using selected additives. Our goal is to develop effective rotational programs for organic farming practices with the use of copper and biologicals, as well as conventional programs with the use of antibiotics, copper, biologicals, and other bactericidal compounds for use during bloom and early fruit development.

***Management of postharvest decays.*** Apples like other pome fruits can be stored for some period of time in optimum fruit storage environments. Still, postharvest decays caused by fungal organisms can result in economic crop losses. The major postharvest pathogens of apples are *Penicillium expansum, Botrytis cinerea, Alternaria* *alternata, Mucor piriformis,* and *Neofabraea* spp. causing blue mold, gray mold, Alternaria rot (black mold), Mucor decay, and bull's eye rot, respectively. There is a deficiency in postharvest biocontrols and natural products that are available for preventing these decays in storage. BioSave 100 is one of the few materials currently available in the United States, but its efficacy is limited. Still, other biological products are registered in other countries and these potentially could be evaluated for California conditions if registrants decide to market their products (e.g., Shemer - *Metschnikowia fructicola*, Candifruit - *Candida sake*, Nexy - *Candida oleophila*, Boni-Protect - *Aureobasidium pullulans*) in the U.S.

We previously showed that the bio-fungicide polyoxin-D (Ph-D, Oso, Tavano) is very effective in reducing gray mold and Alternaria rot, but not blue mold. Polyoxin-D was approved as an organic fungicide by the NOSB in April 2018 and is currently pending pre-harvest labeling and postharvest registration on multiple crops. We also demonstrated the efficacy of another bio-fungicide, natamycin (pimaricin). For many years, natamycin has been a federally-approved food additive to prevent mold growth, including *Penicillium* species, on dairy and meat products in the United States and other countries. Over this time, resistance in *Penicillium* species against natamycin has not occurred. This compound was registered in late 2016 as BioSpectra for postharvest treatment of citrus and stone fruits. Natamycin has an exempt registration status and has been submitted to the NOSB for organic registration. In our evaluations, natamycin showed very good and consistent efficacy against gray mold and Mucor rot. Efficacy against blue mold, however, has been very variable over the years ranging from excellent to unsatisfactory. Therefore, our goal is to improve its performance so it potentially can be made available to the pome fruit industry. In 2018/19, we continued to compare several formulations of natamycin, and we tried to determine the causes for its inconsistency.

**OBJECTIVES FOR 2018-2019**

***Fire blight research***

1. Evaluate the efficacy of treatments for managing fire blight.
   A. Evaluate growth enhancers (e.g., buffers) of biological control agents in lab and field trials.
   B. Laboratory in vitro tests on copper and zinc products (registered copper products) with newly identified antibacterial, food additives (lactic acid, poly-L-lysine, and nisin) and experimental compounds (SBH derivatives) that enhance the activity of copper and possibly zinc.
   D. Field trials with protective air-blast spray treatments:
      i. Kasugamycin in combination with organic treatments to support organic petition to NOSB.
      ii. New formulations of copper (e.g., Badge X2, CS-2005, Cueva) and SBH as a copper activity enhancer in combination or rotation with newly identified antibacterial, food additives (lactic acid, poly-L-lysine, and nisin).
      ii. Biological treatments (Blossom Protect, Serenade) with and without the addition of growth enhancers.
      iii. Blockers of bacterial infection that interfere with Type III secretion systems (e.g., TS products) alone or in mixtures with other biological control treatments.

***Postharvest research***

2. Comparative evaluation of new postharvest fungicides
   A. Evaluate natamycin (BioSpectra) and other new postharvest fungicides such as Academy at selected rates against gray mold, blue mold, Alternaria decay, and bull's eye rot and compare to fludioxonil.
   B. Evaluate mixtures of these compounds.

**PLANS AND PROCEDURES**

***Isolation and culturing of* E. amylovora *and sensitivity testing against antibiotics and copper.*** Fire blight samples were obtained from pome fruit trees in the spring of 2018 from commercial orchards. Infected plant material 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 *E. amylovora* (Appl. Environ. Microbiol. 58:3522-2536). Strains were tested for their sensitivity to streptomycin and oxytetracycline using the spiral gradient dilution (SGD) method. Copper sensitivity of strains was determined by streaking bacterial suspensions (70% transmission at 600 nm) on CYE (casitone, yeast extract, glycerol) or nutrient agar amended with 0, 20, 30, or 40 ppm MCE. Growth was recorded after 2 days of incubation at 25C and was rated as +++ (growth not inhibited, similar to the control), ++ (growth inhibited as compared to the control), or + (growth sparse).

The toxicity of ε-poly-L-lysine and nisin against *E. amylovora* was evaluated in direct contact assays. For this, suspensions of a strain of *E. amylovora* were incubated in final concentrations of 500 ppm of these antimicrobials, and water was used in control treatments. To possibly improve the toxicity of ε-poly-L-lysine and nisin, ethylenediaminetetraacetic acid (EDTA) was added using selected concentrations. Mixtures were incubated for 30 min, diluted 1:1000 with sterile water, and aliquots were then plated onto nutrient agar. After 2 days, bacterial colonies were enumerated, and percent inhibition in colony formation as compared to the control was calculated.

***Field studies on the management of fire blight using protective treatments.*** Air-blast field studies on the relative efficacy of protective treatments were conducted in experimental cvs. Granny Smith and Fuji apple orchards at the Kearney Agricultural Research and Extension Center (KARE). All trees received a copper treatment at bud break to help reduce the high amount of inoculum present in these orchards that made evaluation of bactericide treatments difficult in the last couple of years. Four applications were done starting at 5-10% bloom and followed by phenology-based treatments until petal fall. Treatments included single treatments, mixtures, and a rotation. Incidence of blight was assessed in late May based on the number of infected flower clusters of approximately 200 clusters evaluated for each of the four two-tree replications. Additionally, potential phytotoxic effects of the treatments (e.g., fruit russeting and leaf burn) were evaluated. For comparison, field studies were also conducted on Bartlett pear with some overlapping treatments to the apple studies. Four applications were done, and disease was evaluated in early May. Data were analyzed using analysis of variance and LSD mean separation procedures of SAS 9.4.

In small-scale field studies at UC Davis, two new experimental biocontrol agents (coded BC250 and T3-07) were evaluated. Treatments were applied to open flowers of Fuji apple or Comice pear using a hand sprayer. Flowers were inoculated with *E. amylovora* after 3.5 h, and peroxyacetic acid (e.g., Oxidate) was applied as a secondary treatment to some of the primary treatments after another hour. Streptomycin was used as standard treatment for comparison. Disease was evaluated after 1 week. Data were statistically analyzed as described above.

***Efficacy of new postharvest fungicides for managing apple decays in storage.*** A new high-solution formulation of natamycin was compared to the BioSpectra formulation using Granny Smith apple inoculated with *P. expansum* or *B. cinerea*. The new formulation was also evaluated for its efficacy to control blue mold of Granny Smith apple, Shinko apple pear, as well as Bartlett, D'Anjou, and Bosc pear in the laboratory. Fruit were treated using an air-nozzle sprayer after 12 h and then incubated for 7 days at 20C.

Granny Smith fruit that were treated similar to commercial practices concerning harvest, handling, packing, and temperature-management of fruit were used in an experimental packingline study at KARE. Fruit were wound-inoculated with conidial suspensions of *B. cinerea* or *P. expansum* and treated after 15 to 16 h with BioSpectra or Scholar by in-line drenches that were followed by a CDA application with a carnauba-based fruit coating (i.e., Decco 230). For each of four replications, 24 fruit were used. Data were analyzed using analysis of variance, and averages were separated using least significant difference mean separation procedures of SAS 9.4.

## RESULTS AND DISCUSSION

***Survey of antibiotic and copper sensitivity in* E. amylovora *strains from California.*** In 2018, 70 strains were obtained from 13 orchard locations in Sacramento Co. and tested. All strains were found to be sensitive to **kasugamycin** (Table 1). Resistance to **streptomycin** was detected in all but one location. A low incidence of resistance (2 of 6 isolates) was present in an orchard where only copper and Serenade were applied for fire blight management. Forty-two of the resistant strains from the survey had plasmid-based moderate resistance (MIC <20 ppm) and 19 strains displayed high resistance that most likely was chromosomal-based. For these latter strains streptomycin concentrations of up to 40 ppm were tested, but based on our previous results, these strains typically still grow at >2000 ppm. In one location all 6 resistant strains, and in another location, 6 of the 7 strains were highly resistant. This high incidence of high resistance is interesting because in our surveys several years ago, high-resistance was present only at very low levels. Thus, as we demonstrated previously, the occurrence of streptomycin resistance fluctuates widely among years and probably reflects strain fitness and antibiotic use. Overall, there was no clear correlation between streptomycin usage in 2018 and the incidence and level of streptomycin resistance that was present in the pathogen population (Table 1). However, the previous seasons' applications possibly also need to be considered that will determine the composition of the overwintering pathogen population.

Results over the years support our recommendation that streptomycin can be used once a year effectively for most growers. In years with high- to moderate disease levels, pathogen populations exposed to multiple applications of streptomycin will be under selection pressure of the antibiotic, and this will allow re-emergence of resistant sub-populations.

In our evaluations of **oxytetracycline** toxicity against *E. amylovora* strains from the 13 orchard locations, surprisingly we detected high levels of resistance with growth at >40 ppm in the spiral gradient endpoint assay at two locations (6 of 7 strains tested in one orchard and 1 of 8 strains tested in another orchard; Table 1). These resistant strains were also highly resistant to streptomycin. In the location with the highest incidence of $Oxy^R$, nine applications of the antibiotic were applied between 2017 and 2018. High dependency on one antibiotic in a two-year period may be responsible for the selection of the resistance detected. The strains' identity was verified as *E. amylovora* by specific PCR primers, and their resistance was confirmed by culturing on nutrient agar amended with 40 ppm oxytetracycline (Table 1). Oxytetracycline resistance in *E. amylovora* has never been reported previously at this high level, and this finding is of serious concern. Considering the wide fluctuations in streptomycin resistance in California pear orchards and the previously described non-persistent population of the pathogen with reduced sensitivity to oxytetracycline, it is currently not known if these new resistant strains are competitively fit and will persist in the absence of selection pressure (i.e., applications with oxytetracycline and streptomycin). We plan to characterize these strains genetically to determine if oxytetracycline resistance genes are similar to those that were previously described from other bacteria (non-plant pathogens).

Regarding **copper** sensitivity, growth of all 70 strains was completely inhibited on CYE (a growth medium with a low copper-binding capacity) agar amended with 20 ppm MCE (Table 1). All strains grew on the nutrient-rich nutrient agar at 20 ppm MCE similar as on non-amended agar. At 30 ppm MCE on nutrient agar, confluent growth of most strains was reduced or inhibited. Thus, as in 2015- 2017, current *E. amylovora* populations are considered moderately copper-resistant. Again, we observed the frequent presence of spontaneous mutant colonies emerging at higher copper concentrations. These mutants were not stable when sub-cultured on copper-free media and reverted back to sensitivity. If these mutants also occur in the field, however, under continued presence of selection pressure (i.e., copper sprays) they may successfully compete and cause disease.

Previously, we outlined several factors that likely contributed to the failure of copper applications to control fire blight. Here, we re-summarize this information: 1) Highly conducive disease conditions may allow the pathogen to overcome the suppressive action of copper (copper is bacteriostatic and does not kill the pathogen); 2) Only low rates of copper are registered for fire blight management; 3) There is moderate copper resistance in *E. amylovora;* and 4), Selection of populations (spontaneous mutants) with higher copper resistance after repeated applications may lead to disease in the presence of copper. Fruit russetting also may occur on some pome fruit varieties with repeated applications of copper. Therefore, there is a need to develop and register products that have different modes of action and that potentially can be registered as organic products.

***In vitro toxicity of ε-poly-L-lysine and nisin against* E. amylovora.** In 30-min direct exposures of *E. amylovora* suspensions, colony formation was reduced by 40 or 50% using nisin or ε-poly-L-lysine, respectively (Fig. 1). The toxicity of both food additives was significantly increased with the addition of 100 or 500 ppm EDTA. Growth was completely inhibited by adding 500 ppm EDTA to either bactericide and by approximately 80 or 100% using 100 ppm EDTA with ε-poly-L-lysine or nisin, respectively; EDTA by itself was only moderately or not inhibitory, depending on the rate used. These results indicated that the toxicity of nisin and ε-poly-L-lysine could be increased, and this was subsequently evaluated in field efficacy studies.

***Field studies on fire blight using protective treatments.*** Fire blight incidence in our research plots in the spring of 2018 was high on apple, i. e., over 40% based on infected flower clusters of untreated control trees. Disease, however, was low on Bartlett pear due to cool temperatures during bloom time. The latter orchard location often had very high disease levels over the years. On Granny Smith apple, Blossom Protect with the newly formulated buffer additive was the most effective treatment, and disease incidence was reduced from 42.4% in the control to 11.1% (Fig. 2). The rotation treatment of Badge, Badge + ProPhyt, followed by two applications of Blossom Protect, however, was somewhat less effective. Statistically similarly effective treatments to Blossom Protect were Kasumin + FireWall, Kasumin + ε-poly-L-lysine + zinc oxide, as well as Kasumin 2L and Kasumin 4L by themselves. Nisin and ε-poly-L-lysine by themselves were only moderately effective, and the addition of EDTA and zinc oxide to nisin or of Dart (28.3% capric and 41.7% caprylic acids) to ε-poly-L-lysine only resulted numerical but not statistically significant increases in efficacy. The three organic copper products Cueva, Mastercop, and CS-2005 also had moderate activity, with Cueva being the most effective. No phytotoxicity was observed using any of the treatments.

On Fuji apple, Kasumin 2L and 4L, and FireLine + zinc oxide + Dart provided the highest efficacy among treatments evaluated (Fig. 3). Among treatments containing the preservatives nisin or ε-poly-L-lysine, ε-poly-L-lysine + zinc oxide + EDTA was most effective. In the latter mixture treatment, ε-poly-L-lysine at the lower rate of 3.5 oz was more effective that at the 13.5-oz rate. Interestingly, in vitro direct exposure studies also indicated that this compound was more toxic at lower rates used. Thus, this needs to be further explored. ε-poly-L-lysine is a very large molecule, and lower concentrations possibly have better access to target sites and prevent auto-binding to itself. Two new potential biocontrol agents that showed activity in vitro were provided to us and were evaluated in small-scale studies on Fuji apple and Comice pear trees. In contrast to treatments with streptomycin, the incidence of blighted flowers as compared with the control was not reduced using these bacteria (Fig. 4). We followed a protocol specified by the provider of the bacteria, and a different treatment-inoculation schedule (e.g., longer time between treatment and inoculation) may improve the effectiveness. These results also stress the difficulty in making potential biocontrol agents that show activity in the lab to be effective treatments in the field.

In a field trial on Bartlett pear, all treatments evaluated significantly reduced the disease from the control, mostly to low levels (Fig. 5). Kasumin + FireWall showed the least amount of blight. With a disease incidence in the control of less than 8%, Serenade + Cueva and Nisin + EDTA + zinc oxide also performed well, however, Nisin + EDTA was the least effective treatment. Three new experimental treatments (NSA, NS1, and NS2) had moderate to good efficacy, and the best one (i.e., NS2) should be evaluated at higher disease pressure).

In our spring 2019 field trials on the management of fire blight, numerous compounds were evaluated that often were used in mixtures. Because it was not possible to test each mixture compound by itself in a field study with trees, it is often difficult to determine which of the mixture components improved efficacy, especially when triple mixtures were used. Some conclusions, however, can be made. ε-poly-L-lysine and nisin have potential as fire blight management treatments, especially considering that they are currently have generally regarded as safe (GRAS) status as food additives by the US Food and Drug Administration (FDA). Zinc oxide did not improve the efficacy of Mycoshield + LI700 at the rate evaluated but improved the efficacy of the Nisin + EDTA treatment (Fig. 5). Formulations are very difficult to develop and require expertise from formulation chemists. As indicated above, lower rates of these components may be better in combination with the active ingredient than higher rates. Thus, we are pursuing development of formulations in cooperation with a potential registrant. Developing these new modes of action is critical in providing safe, effective alternatives to current products registered and for reducing the risk of resistance development to existing registered products as rotational or mixture treatments.

In conclusion, among organic treatments, only Blossom Protect showed acceptable commercial efficacy in the management of fire blight similar to standards. Conventional treatments containing the antibiotics streptomycin or kasugamycin were always very effective. Still, other biological treatments to be considered are the liquid copper formulation Cueva and the preservatives nisin and ε-poly-L-lysine. Formulating these antimicrobial food preservatives to improve their efficacy needs to be done in cooperation with a potential registrant. Nisin and ε-poly-L-lysine are eligible for biopesticide registration with the US-EPA. Kasumin is currently considered a conventional treatment, however, efforts are underway to obtain an organic registration. The compound is a natural substance that is commercially produced by fermentation of *Streptomyces* species. In contrast to streptomycin and oxytetracycline, it has very minimal or no usage in human and veterinary medicine. Thus, an organic registration seems plausible.

***Evaluation of postharvest treatments using single-fungicides, mixtures, and pre-mixtures.*** Postharvest studies focused on the efficacy of the new natural compound natamycin that is currently registered as a biopesticide with tolerance exemption status by the US-EPA. The fungicide is registered as BioSpectra on citrus and stone fruits. In laboratory studies, we compared the efficacy of two formulations for the control of blue mold and gray mold, the commercial BioSpectra and a high-solubility solution formulation. Previously, we determined that the WP formulation is generally less effective. In this year's studies, the high-solubility formulation was numerically more effective as shown in Fig. 6 for a study on Granny Smith apple (and also in other trials on pome and other fruits that are not presented here). For blue mold control, we found natamycin to be highly effective on Granny Smith apple, but not on apple pear and three pear cultivars (Fig. 7). We noted this difference in efficacy among pome fruit cultivars previously, and control of blue mold of pears with natamycin has been a challenge for several years because the fungicide is highly effective on other decays such as gray mold, Alternaria, and Rhizopus rot (even when inoculated on the same fruit that are also inoculated with *P. expansum*). In doing numerous studies over early to late fall, we also noted differences in efficacy of natamycin among sources of apple fruit that likely were related to the fruit age (time of storage after harvest). Thus, late-season tests with Granny Smith apple were generally not very successful, although Scholar still was effective. We are planning to do all our postharvest studies with natamycin soon after harvest in 2019 when commercial postharvest treatments are mostly done in California.

In an experimental packingline study using in-line drench applications, BioSpectra significantly reduced blue mold and gray mold of Granny Smith apple, and the 1000-ppm rate was more effective than the 500-ppm rate for blue mold (Fig. 8). A treatment with 300 ppm Scholar was significantly more effective than those with BioSpectra. Based on the moderate efficacy of natamycin, natamycin may not become registered on pome fruits unless it is developed in a premixture with other fungicides. Still, we will continue to try to improve its efficacy. Moreover, natamycin still has a chance to receive an OMRI listing with our NOSB petition. Mixtures of BioSpectra with Scholar or Academy were evaluated previously by us and were very effective against blue mold, gray mold, Alternaria rot and bull's eye rot. Although efficacy is not improved as compared to using the two registered fungicides by themselves, adding natamycin represents an excellent resistance management strategy. Resistance to natamycin has not been reported previously to any *Penicillium* species, although the compound has been registered for food uses for over 20 years.

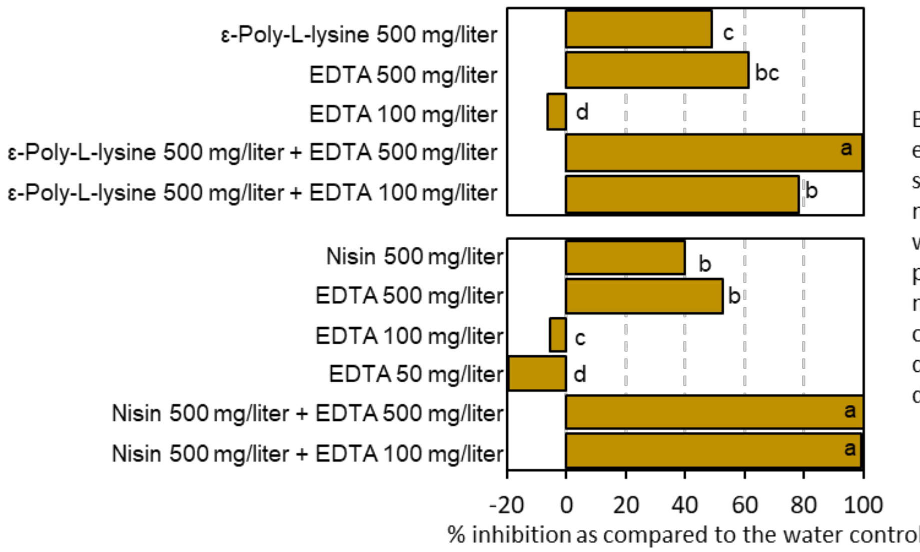
Table 1. Sensitivity of *E. amylovora* strains from pear orchards in Sacramento Co. to streptomycin, oxytetracycline, kasugamycin, and copper in 2018

| | | | | Copper | | | | |
|---|---|---|---|---|---|---|---|---|
| | Strepto- | Oxytetra- | Kasuga- | CYE | Nutrient agar | | | |
| Location | mycin | cycline | mycin | 20 ppm | 20 ppm | 30 ppm | 40 ppm | Chemical spray program |
| 1 | MR | S | S | -- | ++ | +* | - | Oxy (3)- Strep (1) rotation |
| | HR | S | S | -- | +++ | * | - | |
| | MR | S | S | -- | +++ | * | - | |
| 2 | HR | HR | S | -- | +++ | * | - | |
| | HR | HR | S | -- | +++ | * | - | |
| | HR | HR | S | -- | +++ | * | - | Oxy (3)- Strep (1) rotation |
| | HR | HR | S | -- | +++ | * | - | |
| | HR | HR | S | -- | +++ | * | - | |
| | MR | S | S | -- | +++ | ++* | - | |
| | HR | HR | S | -- | +++ | * | - | |
| 3 | HR | S | S | -- | +++ | * | - | Oxy (4)- Strep (1)- PO3 (2) |
| | HR | S | S | -- | +++ | * | - | rotation |
| | HR | S | S | -- | +++ | * | - | |
| | MR | S | S | -- | +++ | ++* | - | |
| | MR | S | S | -- | +++ | ++* | - | |
| | MR | S | S | -- | +++ | +* | - | |
| | HR | S | S | -- | +++ | * | - | |
| | HR | S | S | -- | +++ | * | - | |
| 4 | MR | S | S | -- | +++ | +* | - | Oxy (4)- Strep (1)- PO3 (2) |
| | MR | S | S | -- | +++ | +* | - | rotation |
| 5 | MR | S | S | -- | +++ | +* | - | Oxy (4)- Strep (1)- PO3 (2) |
| | MR | S | S | -- | +++ | * | - | rotation |
| | MR | S | S | -- | +++ | * | - | |
| | MR | S | S | -- | +++ | * | - | |
| 6 | S | S | S | -- | +++ | ++ | * | Oxy (4)- Strep (1)- PO3 (2) |
| | S | S | S | -- | +++ | ++ | * | rotation |
| | S | S | S | -- | +++ | ++ | * | |
| | S | S | S | -- | +++ | ++ | * | |
| 7 | MR | S | S | -- | +++ | * | - | Copper, Oxy-Strep |
| | MR | S | S | -- | +++ | * | - | mixtures, rotated with |
| | MR | S | S | -- | +++ | ++* | * | Strep, Kasu |
| 8 | MR | S | S | -- | +++ | * | - | Copper, Oxy-Strep |
| | MR | S | S | -- | +++ | * | - | mixtures, rotated with |
| | MR | S | S | -- | +++ | * | - | Strep, Kasu |
| | MR | S | S | -- | +++ | * | - | |
| | MR | S | S | -- | +++ | * | - | |
| | MR | S | S | -- | +++ | * | - | |
| 9 | MR | S | S | -- | +++ | * | - | Copper, Oxy-Strep |
| | MR | S | S | -- | +++ | * | - | mixtures, rotated with |
| | MR | S | S | -- | +++ | +* | - | Strep, Kasumin |
| | MR | S | S | -- | +++ | * | - | |
| | MR | S | S | -- | +++ | ++* | - | |
| | MR | S | S | -- | +++ | ++* | - | |
| 10 | HR | S | S | -- | +++ | * | - | Oxy (3)- Strep (2) rotation |
| | HR | S | S | -- | +++ | * | - | |
| | HR | S | S | -- | +++ | * | - | |
| | HR | S | S | -- | +++ | * | - | |
| | HR | S | S | -- | +++ | * | - | |
| | HR | S | S | -- | +++ | * | - | |
| 11 | MR | S | S | -- | +++ | * | - | Oxy (3)- Strep (2) rotation |
| | MR | S | S | -- | +++ | ++* | - | |
| | MR | S | S | -- | +++ | ++* | - | |
| | MR | S | S | -- | +++ | * | - | |
| | MR | S | S | -- | +++ | * | * | |
| | MR | S | S | -- | +++ | * | * | |
| | MR | S | S | -- | +++ | ++ | * | |
| 12 | MR | S | S | -- | +++ | ++ | * | Oxy-Strep mixtures |
| | MR | S | S | -- | +++ | ++ | * | |
| | MR | S | S | -- | +++ | ++ | * | |
| | MR | S | S | -- | +++ | ++ | * | |
| | MR | S | S | -- | +++ | ++ | * | |
| | S | S | S | -- | +++ | ++ | * | |
| | HR | HR | S | -- | +++ | ++* | * | |
| | MR | S | S | -- | +++ | +++ | * | |
| 13 | S | S | S | -- | +++ | ++* | * | Copper, Serenade |
| | S | S | S | -- | +++ | * | * | |
| | S | S | S | -- | +++ | ++ | * | |
| | MR | S | S | -- | +++ | ++ | * | |
| | S | S | S | -- | +++ | +* | * | |
| | MR | S | S | -- | +++ | * | * | |

Sensitivity to streptomycin, oxytetracycline, and kasugamycin was determined using the spiral gradient endpoint method. S = sensitive, MR = moderately resistant (MIC = <20 ppm), HR = highly resistant (MIC = >40 ppm).

Sensitivity to copper was determined by growth on amended CYE (casitone, yeast extract, glycerol agar) or nutrient agar. Copper ratings: +++ = growth similar to non-amended agar, ++ = reduced growth, + = little growth, - = no growth. * = Spontaneous mutants growing, but no confluent growth.

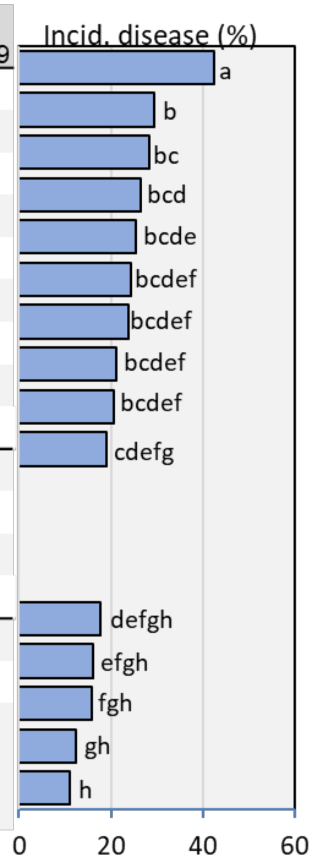
Fig. 1. In vitro toxicity of ε-poly-L-lysin and nisin against *E. amylovora* - Direct exposure studies




Bacteria were exposed to the test substances for 30 min, diluted 1:100 with water, and then plated onto agar media. Bacterial colonies were quantified after 2 days.

Fig. 2. Efficacy of new mostly organic bactericides for management of fire blight of Granny Smith apples, Fresno Co. 2019

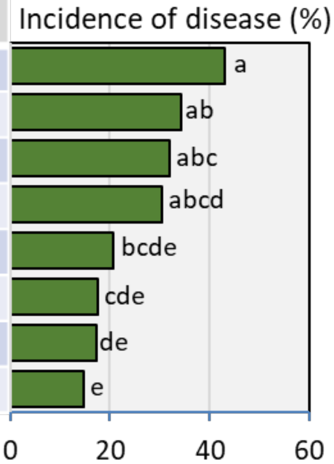
| Treatment | Rate | 3-30 | 4-4 | 4-10 | 4-19 |
|---|---|---|---|---|---|
| Control | --- | --- | --- | --- | --- |
| ε-Poly-L-lysine | 3.5 oz | @ | @ | @ | @ |
| MasterCop | 64 fl oz | @ | @ | @ | @ |
| CS-2005 | 25 fl oz | @ | @ | @ | @ |
| Nisin | 13.5 oz | @ | @ | @ | @ |
| ε-Poly-L-lysine + Dart | 3.5 oz + 45 fl oz | @ | @ | @ | @ |
| Nisin + EDTA + Zinc oxide | 13.5 oz + 40 fl oz + 32 oz | @ | @ | @ | @ |
| "New" Mycoshield | 8 oz | @ | @ | @ | @ |
| Cueva | 96 fl oz | @ | @ | @ | @ |
| Rotation: Badge X2 | 16 oz | @ | --- | --- | --- |
| Rotation: Badge X2 + ProPhyt | 16 oz + 64 fl oz | --- | @ | --- | --- |
| Rotation: Blossom Protect + Buffer | 20 oz + 5 lb | --- | --- | @ | --- |
| Rotation: Blossom Protect + Buffer | 20 oz + 5 lb | --- | --- | --- | @ |
| Kasumin 4L | 32 fl oz | @ | @ | @ | @ |
| Kasumin 2L | 64 fl oz | @ | @ | @ | @ |
| Kasumin 2L + ε-Poly-L-lysine + Zinc oxide | 64 fl oz + 13.5 + 32 oz | @ | @ | @ | @ |
| Kasumin 2L + FireWall | 64 fl oz + 8 oz | @ | @ | @ | @ |
| Blossom Protect + Buffer | 20 oz + 5 lb | @ | @ | @ | @ |




All trees received a bud break treatment with 6 lb ChampION/A on 3-25-19. In-season treatments were applied on 3-30 (5-10% bloom), 4-4 (20-40% bloom), and 4-10-18 (full bloom), and 4-19 (petal fall) using an air-blast sprayer. Disease was evaluated on 5-21-19. "New" Mycoshield formulation = NUP 17010.

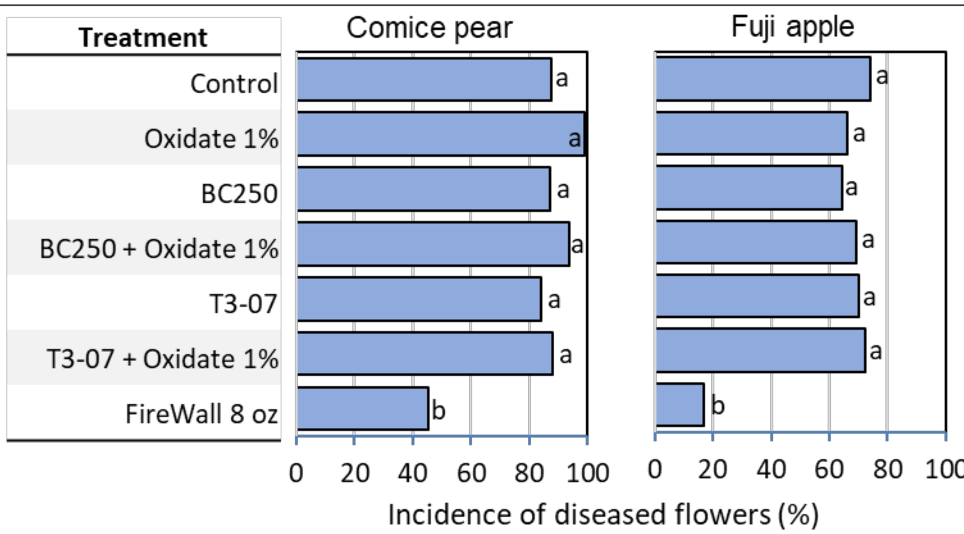
Fig. 3. Efficacy of bactericides for management of fire blight of Fuji apples, Fresno Co. 2019

| Treatment | Rate/A |
|---|---|
| Control | --- |
| Nisin + EDTA + Zinc Oxide | 13.5 oz + 40 oz + 32 oz |
| ε-Poly-L-lysine + Dart | 13.5 oz + 45 fl oz |
| ε-Poly-L-lysine + Zinc Oxide + EDTA | 13.5 oz + 32 oz + 40 fl oz |
| ε-Poly-L-lysine + Zinc Oxide + EDTA | 3.5 oz + 32 oz + 40 fl oz |
| Kasumin 4L | 32 fl oz |
| FireLine + Zinc Oxide + Dart | 16 oz + 32 oz + 45 fl oz |
| Kasumin 2L | 64 fl oz |




All trees received a bud break treatment with 6 lb ChampION/A on 3-25-19. In-season treatments were applied on 4-2 (5-10% bloom), 4-5 (20-40% bloom), 4-12-18 (full bloom), and 4-22 (petal fall) using an air-blast sprayer at 100 gal/A. Disease was evaluated for 100 flower clusters (spurs) of each tree on 5-20-19. All treatments had four, paired-tree replications (total of 8 trees).

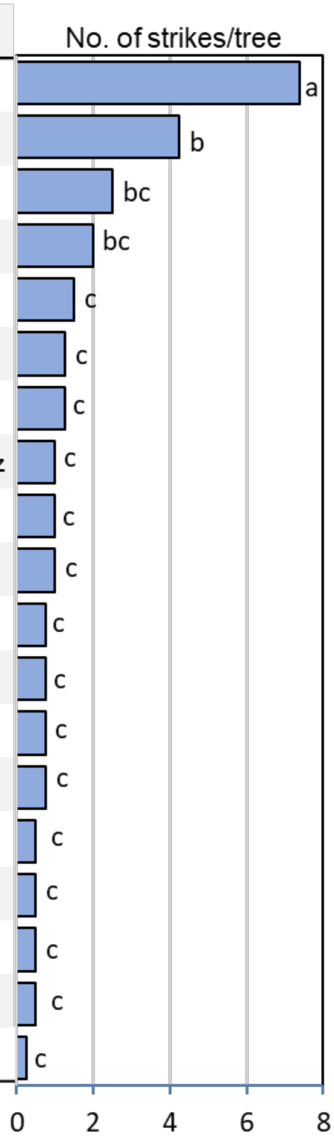
Fig. 4. Efficacy of two new potential bacterial antagonists (BC250, T3-07) in comparison with streptomycin for control of fire blight of Comice pear and Fuji Apple in a small-scale field study at UC Davis 2019




Treatments were applied to open flowers using a hand sprayer. Flowers were inoculated with *E. amylovora* after 3.5 h, and Oxidate was applied after another hour. Disease was evaluated after 1 week.

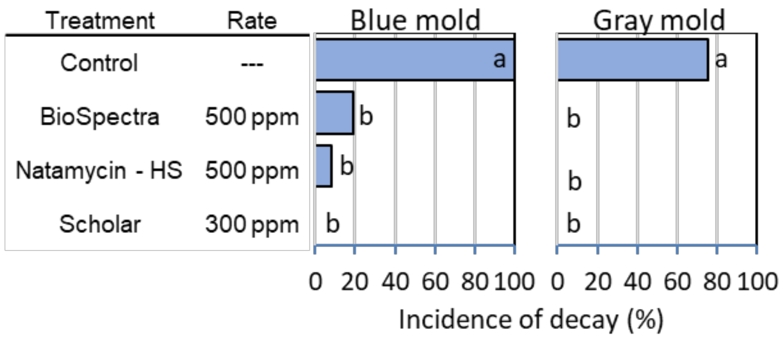
Fig. 5. Efficacy of new bactericides for management of fire blight of Bartlett pear, Sutter Co. 2019

| Treatment | Rate |
|---|---|
| Control | --- |
| Nisin + EDTA | 13.5 oz 32 fl oz |
| NSA + Silco | 135 fl oz + 68 fl oz |
| NS1 + Silco | 135 fl oz + 68 fl oz |
| NS2 + Silco | 135 fl oz + 68 fl oz |
| ε-Poly-L-lysine + ZnNO3 | 13.5 oz + 50 fl oz |
| New Mycoshield + ZnNO3 + LI700 | 8 + 50 fl oz + 8 fl oz |
| Kasumin + ε-Poly-L-lysine + ZnO | 64 fl oz + 13.5 oz + 32 oz |
| New Mycoshield + LI700 | 8 oz + 8 fl oz |
| Cueva | 96 fl oz |
| ε-Poly-L-lysine + DART | 13.5 oz + 44 fl oz |
| Kasumin | 64 fl oz |
| Kasumin + ε-Poly-L-lysine | 64 fl oz + 13.5 oz |
| Blossom Protect + buffer | 20 + 80 oz |
| FireLine + ZnO + LI700 | 16 oz + 32 oz + 8 fl oz |
| Serenade ASO + Cueva | 64 + 96 fl oz |
| Nisin + EDTA + ZnO | 13.5 + 32 + 32 oz |
| Kasumin 4L | 32 fl oz |
| Kasumin + Firewall | 64 fl oz + 8 oz |



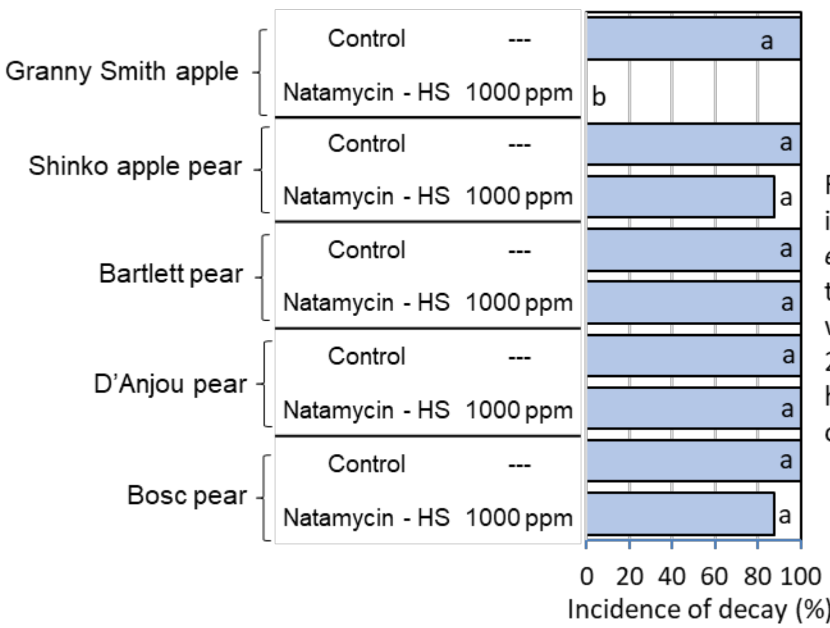

Treatments were applied on 4-4 (5% bloom), 4-12 (full bloom), 4-18 (petal fall), and 4-26-19 (petal fall) using an air-blast sprayer at 100 gal/A. Disease was evaluated on 5-1-19.

Fig. 6. Evaluation of postharvest treatments with two formulations of natamycin for managing postharvest decays of Granny Smith apple in laboratory studies



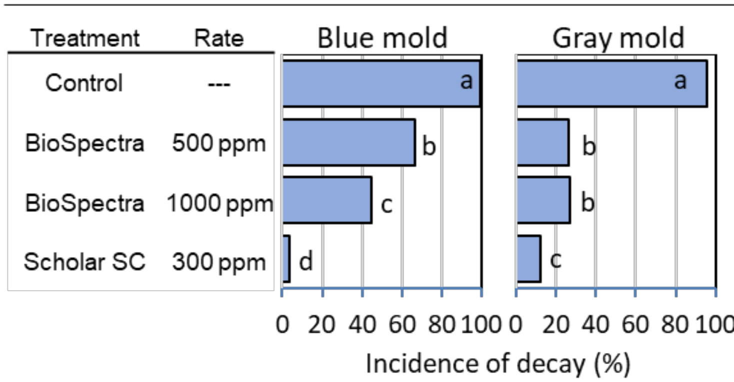

Fruit were wound-inoculated with *P. expansum* or *B. cinerea* and spray-treated after 12 h. Fruit were then incubated at 20C. Natamycin – HS = a high-solution formulation of natamycin.

Fig. 7. Evaluation of postharvest treatments with natamycin for managing postharvest blue mold of pome fruit cultivars in a laboratory study




Fruit were wound-inoculated with *P. expansum* and spray-treated after 12 h. Fruit were then incubated at 20C. Natamycin – HS = a high-solution formulation of natamycin.

Fig. 8. Evaluation of postharvest treatments with natamycin and Scholar for managing postharvest decays of Granny Smith apple in an experimental packingline study




Fruit were wound-inoculated with *P. expansum* or *B. cinerea* and treated by aqueous in-line drench applications with fungicides after 15-16 h. Fruit were sequentially treated with a CDA application with diluted carnauba wax. Fruit were then incubated at 20C for 7 days.

## Mechanism of low-dose irradiation on expression of genes involved in ethylene biosynthesis in 'Granny Smith' apples

Superficial scald is a physiological disorder characterized by skin browning that appears during or after storage of 'Granny Smith' apples. The mechanism for scald development is not fully understood, but it is hypothesized that scald formation is related to increased ethylene production. In apples, low dose irradiation induced ethylene reduction appears to be directly related to prevention of superficial scald. However, the molecular basis of such an irradiation-induced effect is not known. In this study, effort was made to better understand the molecular basis of the decrease in superficial scald and ethylene production in 'Granny Smith' apples after treatment with x-ray irradiation. Apple fruit were exposed to x-ray irradiation treatment either at 310 Gy or 1000 Gy and ethylene production, ACC oxidase enzyme activity and expression of the genes responsible for ethylene biosynthesis were measured after 0, 90, and 180 days of storage plus 7 days at room temperature. Ethylene production of irradiated apples was lower compared to control ($P<0.05$). No difference was observed in ACC oxidase activity at day 0, but irradiation at 310 Gy and 1000 Gy reduced enzyme activity at days 90 and 180 ($P<0.05$). Irradiation treatment reduced the expression of ACS1 and ACO1 ethylene biosynthesis genes ($P<0.05$), which had a high correlation with ACC oxidase enzyme activity. Irradiation did not have a significant effect on other ethylene biosynthesis genes ACS3 and ACO2. Irradiated apples also exhibited lower expression of α-farnesene synthase gene expression.  Thus inhibition of scald was related to suppression of gene expression of key enzymes involved in ethylene biosynthesis as well as production of α-farnesene by irradiation.  Further analysis of results is pending to determine if irradiation induced reactive oxygen species also inactivate the enzymes directly.

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**Project Title:** Study on Mechanical Mass Harvesting of Cling Peaches
**Project Leader:** Stavros Vougioukas.
**Collaborators**: Elizabeth Mitcham.
**Location:** Biological and Agricultural Engineering Department, Un. of California, Davis.
**Duration:** 01-Jun-2018 - 31-May-2019
**Report Authors:** Stavros Vougioukas, Elizabeth Mitcham, Dennis Sadowski, Kelly Richmond

# 1. INTRODUCTION

Harvesting is one of the most labor-intensive operations in cling peach production. A 2011 UC ANR production cost report for processing peach (cling and freestone) estimated the hand-picking and field-sorting cost for processing peaches at $1,200/acre, using $10.97 per hour for general labor including payroll overhead at 33% (Norton, Hasey, Duncan, Klonsky, & De Moura, 2011). This translated to 78% of the total harvest cost, which includes hauling to the packinghouse, and 29.2% of the total operating per acre cost. Labor cost will increase significantly due to recent legislation. Perhaps the greatest problem though, is that in addition to cost, supply of skilled pickers is decreasing; hence, risk of losing crop is increasing too. Therefore, cling peach growers face a great and urgent need for mechanical harvesting solutions.

Cling peaches can be harvested mechanically using tree shaking and fruit catching systems. However, excessive fruit damage is still a problem. Although improvements in the design of the shaker and the catching system can somewhat improve fruit quality, it is well known that a major source of mechanical damage is due to limb-fruit collisions during fruit-fall through the canopy. Existing shake-and-catch systems cannot address this problem. Some tree architectures, like Y-shaped trees with few overlapping scaffolds are easier to harvest mechanically (Peterson et al., 2005). Prototype limb-shaking harvesters for such trees have been developed with encouraging results (cherries: Peterson, Wolford, 2003a; apples: Peterson, Wolford, 2003 b). However, the majority of existing cling peach orchards in California have not adopted such architectures and solutions for existing orchards are needed.

This three-year research project investigates novel approaches to intercepting fruits at multiple heights during a shake-and-catch operation, so that they are collected before they hit tree branches. Multi-level catch systems have been tried in the past for apples by Rehkugler & Markwardt, (1971) and Millier et al., (1973). Mehlschau et al., (1977) developed a similar system for plums and pears. Systems that intercepted and collected fruits at intermediate heights had better performance compared to systems where fruits just ‘trickled down’ to be collected on a single catching surface.

Using funding by the Pear Advisory Board, the Cling Peach Mechanization Fund, and USDA-NIFA, the Bio-Automation Lab at UC Davis has built detailed models of pears and cling-peach trees and the positions of their fruits (Arikapudi, Vougioukas, Saracoglu, 2015; Arikapudi, Vougioukas, Jiménez- Jiménez, Khosro Anjom, 2016). We have also developed and utilized simulation models to confirm that properly deployed multi-level cylindrical rods that penetrate into the canopy can intercept up to 90% of falling fruits before they hit any (digitized) tree branch (Munic et al., 2016). Of course, this number is an “optimistic” estimate, which however can be used to guide the design process. These results prompted the investigation of alternative designs for multi-level fruit catching surfaces.

The long-term goal is to design, build and test a prototype system that inserts multiple catching surfaces into the canopy before shaking, and effectively reduces fruit damage during shaking and falling. The envisioned system would be compatible with existing fruit tree architectures and – as much as possible – with existing shaking operations and equipment, if with minor modifications.

## 2. Prototype Catching Surface

A prototype catching surface consisting of aluminum booms with inflatable side tubes was constructed at UC Davis. Each boom was made from a three inch square thin-wall aluminum tube nine feet long. Twenty-six holes were drilled on each of two opposite sides of the boom and short lengths of 2 inch PVC pipe were epoxied to each hole in the boom. Tubes formed from 6 mil thick polyethylene film were attached to the PVC pipe nipples with hose clamps. Each tube had a diameter of 2-3/8 inches and length of 16 inches. The tubes could be folded and inserted into the boom and then extended from the boom by supplying a small amount of air pressure to the boom. Two booms were mounted on a carriage frame and spaced 34 inches apart. A third boom without inflatable tubes was placed in the center of the frame to provide support to the free ends of the inflatable fingers. Figure 1 is a drawing of the boom and frame test apparatus mounted on a scaffold.

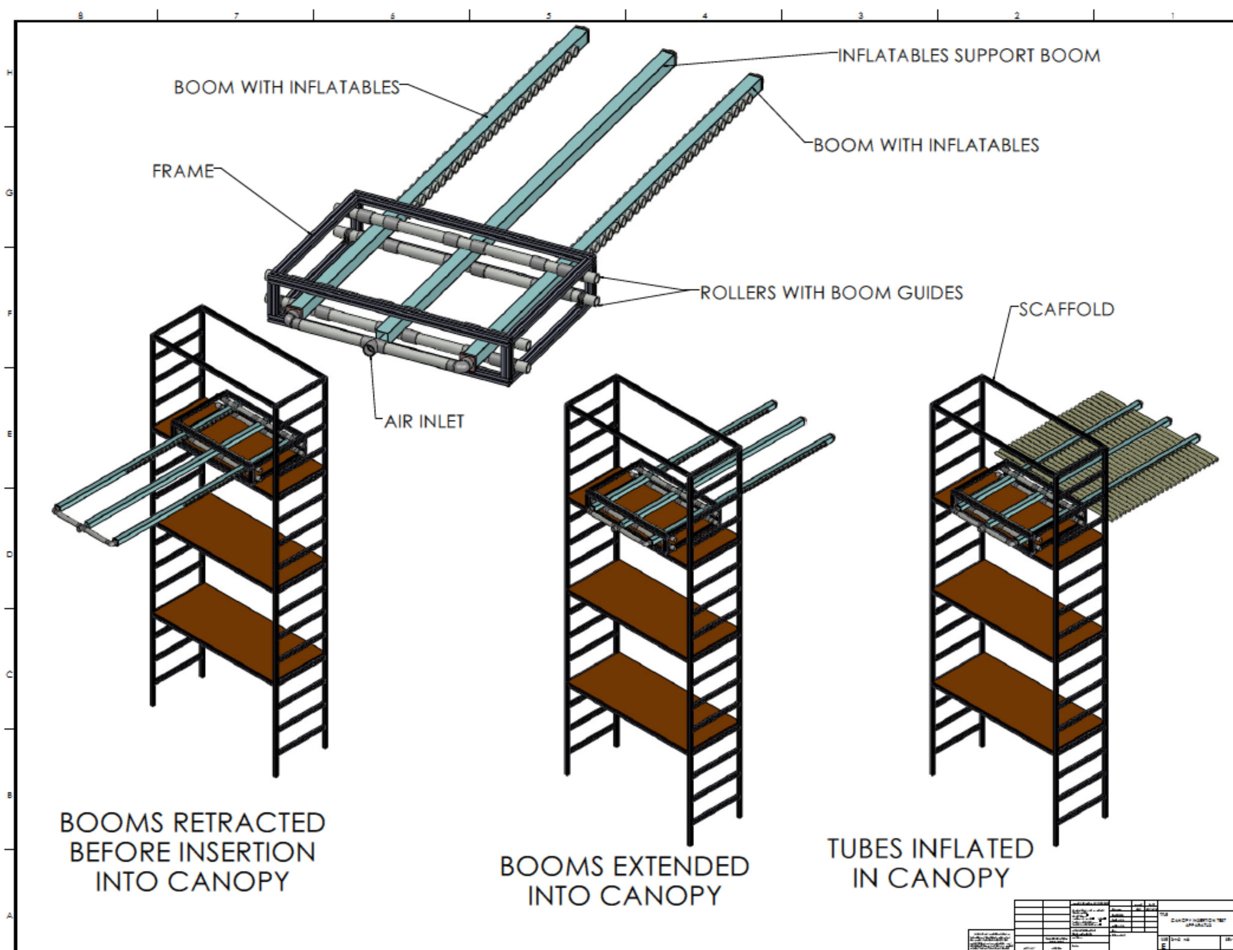


*Figure 1. Boom Insertion Test Apparatus.*

## 3. FRUIT CATCHING EXPERIMENTS

The boom and carriage apparatus described in the previous section was taken to a cling peach orchard at Live Oak, CA owned by Justin Micheli, to determine if fruit landing on the catching surface sustained damage. The peaches were harvested on August 31$^{th}$, 2018 about one week after the peak of commercial ripeness. The orchard we harvested from was severely infested with brown rot. It was difficult to obtain peaches that were not infected with brown rot or directly adjacent to infected fruit. Fruit for the mechanical harvest trials was collected from four different trees with roughly 60 fruits harvested from each tree. Fruit for the control harvest trials was collected from the five trees used for the mechanical harvest plus one additional tree along the same row in the orchard. About 60 fruit were collected from each of these trees. The control harvest fruit were picked by hand, sometimes using shears to separate them from the tree, then placed into boxes for transport back to UC Davis for evaluation.

To simulate fruit shaken loose by a trunk shaker and intercepted by our system, we used the following procedure. The assembly was mounted on a portable hoist with a 16 foot reach which allowed us to easily adjust the height of the catching surface and insert it into the tree canopy by rolling the hoist toward the tree. The booms were inserted into the canopy approximately 12 inches below the highest fruit-bearing branches and the tubes were inflated. To complete the boom insertion testing, the booms were inserted into a canopy and pressurized to a little more than 1 PSI, causing the tubes to pop out of the booms and reach full inflation. Flexibility of the tubes allowed them to deflect around branches and form a catching surface with only a few gaps. Figure 2 shows the boom and carriage inserted in a canopy and the catching surface. Figure 3 presents more photographs of the catching surface inside a canopy.

*Figure 2 Booms inserted into cling peach tree canopy, as viewed from the side (left) and underneath (right).*



*Figure 3 Catching surface created by inflated tubes, viewed from above (left); underneath (center); sideways (right).*

After the booms were inserted, researchers on ladders reached into the canopy and detached undamaged fruit, allowing it to freely drop onto the catching surface (Figure 4). When that level of fruit had been harvested, the fruit was carefully removed from the catching surface and placed in cardboard boxes. The tubes were then deflated but not withdrawn into the booms and the booms were retracted from the canopy. The assembly was lowered such that the catching surface would again be no more than 12 inches below the desired fruit zone. In a full-scale system layers of catching surfaces would be spaced no more than 12 inches apart to minimize drop distance and subsequent fruit damage. This procedure was repeated at various heights in different trees until approximately 240 samples had been collected. These booms did not incorporate a mechanism to automatically retract the tubes, so the booms were depressurized and the tubes manually refolded and reinserted into the booms. This procedure was repeated for different canopies.

*Figure 4 Fruits after having landed on inflated tubes.*

## 4. POSTHARVEST FRUIT QUALITY EVALUATION

The cling peaches were harvested in the morning then immediately transported back to the Postharvest Center at UC Davis. When the peaches arrived at the Postharvest Center they underwent an initial sorting before going into storage to remove any diseased fruit that might have been missed in the initial harvest. To prevent additional ripening all fruit was stored in a temperature controlled room at 0°C. The peaches were kept at 0°C for 5 days. After the 5 day period we sought to compare our two harvest treatments by performing three evaluations a pre-peel, post-peel, and canning.

### 4.1 Pre-Peel Evaluations

We selected 180 peaches from the control harvest and 180 peaches from the mechanical harvest. Fruit that was most similar in size and ripeness were picked for the evaluations. Each fruit was scored on six main quality traits. These included bruising score, number of bruises, number of punctures, number of scrapes, disease, and insect damage. Every fruit for both treatments was inspected visually for any bruises or wounds it might have occurred during the harvest process. Each bruise, puncture, and scrape was recorded. The bruising score was assigned on a scale of 0-3; 0= no bruises, 1=1-4 bruises, 2=5-9 bruises, 3= +10 bruises. Insect and disease were recorded as a binary measure for each fruit. There was not always a clear line between when one spot of disease or insect injury began and another would begin so we chose to simply mark if the fruit had the specific problem or not.

### 4.2 Post-Peel Evaluations

One day after the pre-peel evaluations were performed all peaches were transported to the UC Davis Food Processing Pilot Plant for the post-peel evaluations. Peaches were run through the Pilot Plant's lye peeling line to achieve a clean peel for the entire fruit and prepare them for canning. Once a peach was peeled it was immediately evaluated using the same quality parameters as the per-peel evaluations. As a peach passed through the lye line it was cut completely in half to remove the pit. We evaluated each half individually and combined the scores of two half pieces to get the score for a whole fruit. After the post-peel evaluation was performed the peaches were canned according to the UC Davis Pilot Plant procedure in a 29.9 degree brix solution.

### 4.3 Canning Evaluations

The final evaluation looked at the level of browning incurred on the peaches after canning. The post canning evaluations occurred 55 days after the peaches were initially canned. We evaluated two sets of cans that corresponded to our two different harvest methods. The first set had 68 total cans from the control harvest and the second set had 62 cans from the mechanical harvest. Because the canning process requires each can to have an identical weight, peach halves that came off the lye peeling line were sometimes cut into even smaller pieces to make the necessary weight. The main piece sizes we encountered were half fruit, quarter fruit, slice, and small piece. For the purpose of this study we are focusing on the two largest sizes the half and quarter fruit. We visually evaluated each fruit piece to determine the amount of browning on the surface. The amount of browning was broken down into five categories based on the amount of surface covered by browning; All, Half, Three Quarter, One Quarter, None.

## 5. RESULTS AND DISCUSSION

### 5.1 Boom Insertion

The boom insertion test showed that rigid booms could be successfully inserted into complex tree canopies to create a substantial soft catching surface for falling fruit. In most instances the booms were able to extend to their limit. If the booms can be made with a little more flexibility to allow them to deflect around limbs, then even greater penetration will be possible. The most challenging environment for boom insertion is at the base of the canopy where the limbs are larger and closer together. Insertion becomes easier higher up in the canopy.

Inexpensive polyethylene film used to make the inflatable fingers is OK for tests like this, but may not be durable enough for long term use. Therefore we have been examining other materials such as heat sealable taffeta and rip stop nylon for use as inflatables.

In typical orchards the spacing between rows of trees is narrow and the canopies may be nearly touching. In such cases long rigid booms will not fit in between the rows of trees. For this reason we have been examining ways to make shorter booms which can then be extended in a telescoping fashion. Booms such as this would not have fingers protruding from the sides. Instead they may have a rigid telescoping tube underneath an inflatable tube. A large number of closely adjacent booms could then form the catching surface. When retracted, the boom array would be narrow enough to drive between rows of trees and when extended would penetrate to the centerline of the canopy. An advantage of telescoping booms is that the fruit could be pulled into the base of the array when the boom is retracted. Details of this system are currently being worked out, but the approach looks promising and a prototypes will be built in Year 3.

## 5.2. Postharvest Fruit Quality

Figure 5 shows the damage occurred on Cling Peaches from "mechanical" and hand harvest methods, whereas Figure 6 and Figure 7 show browning on canned half fruit and quarter fruit pieces. The term "mechanical" is used to refer to the process of detaching peaches from the tree and letting them fall on the inflated tubes.

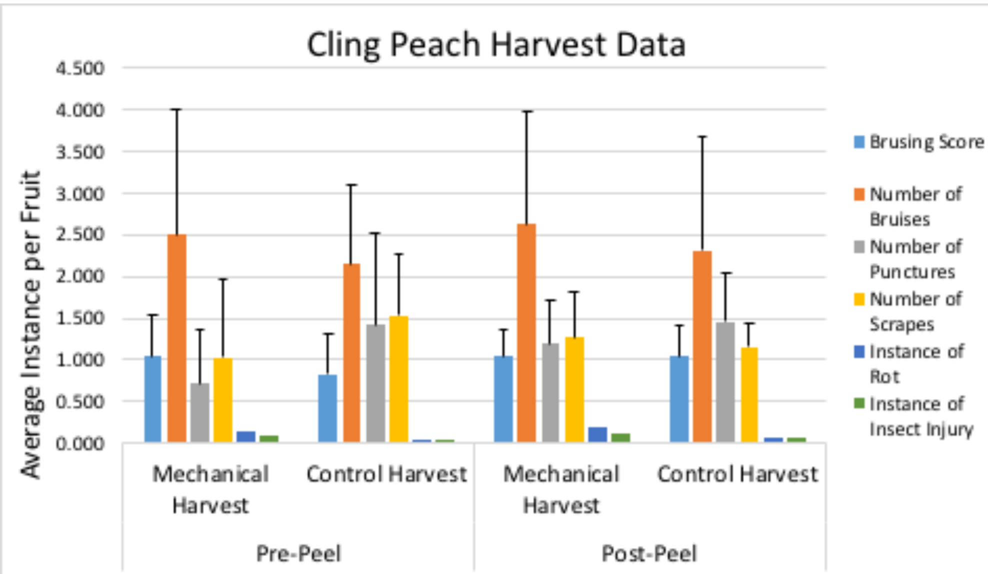


*Figure 5 Damage occurred on Cling Peaches from mechanical and hand harvest methods. Fruit was evaluated using the methods described in section 2.*

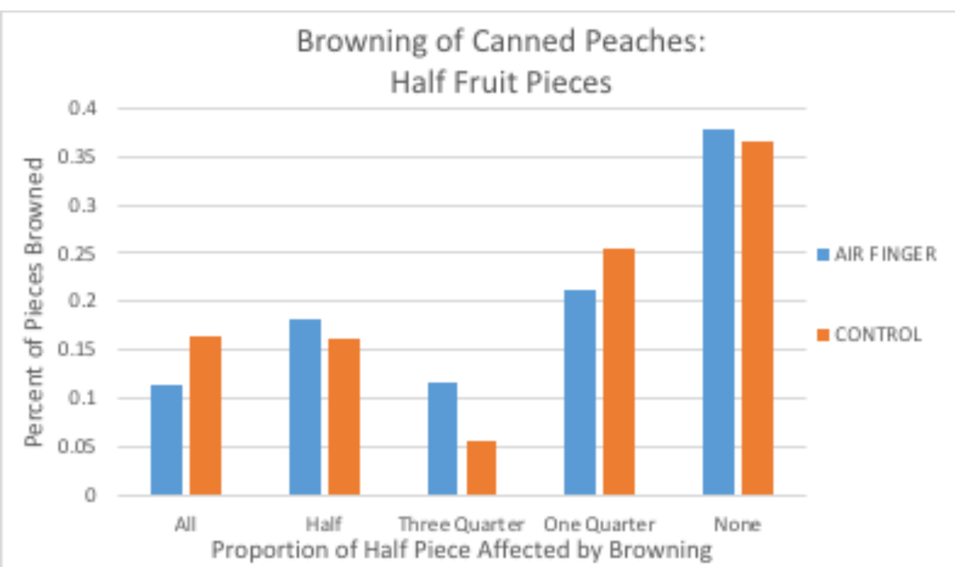

*Figure 6 Amount of browning on canned Cling Peaches. Peach halves from both the control and air tube (mechanical) harvests were evaluated for the amount of browning after canning.*

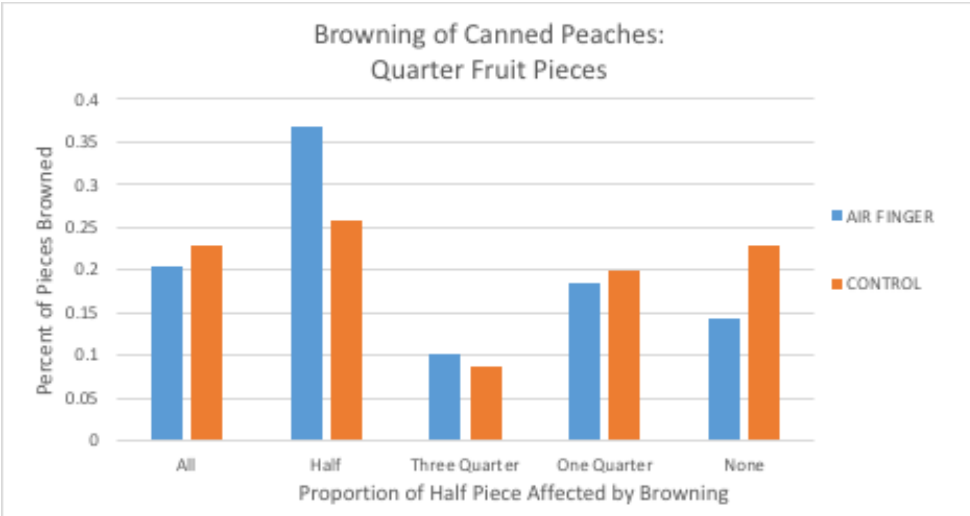


*Figure 7 Amount of browning on canned Cling Peaches. Peach quarters from both the control and air tube (mechanical) harvests were evaluated for the amount of browning after canning.*


*Figure 8 Browning scale used on the Cling Peaches for the post-canning evaluation.*

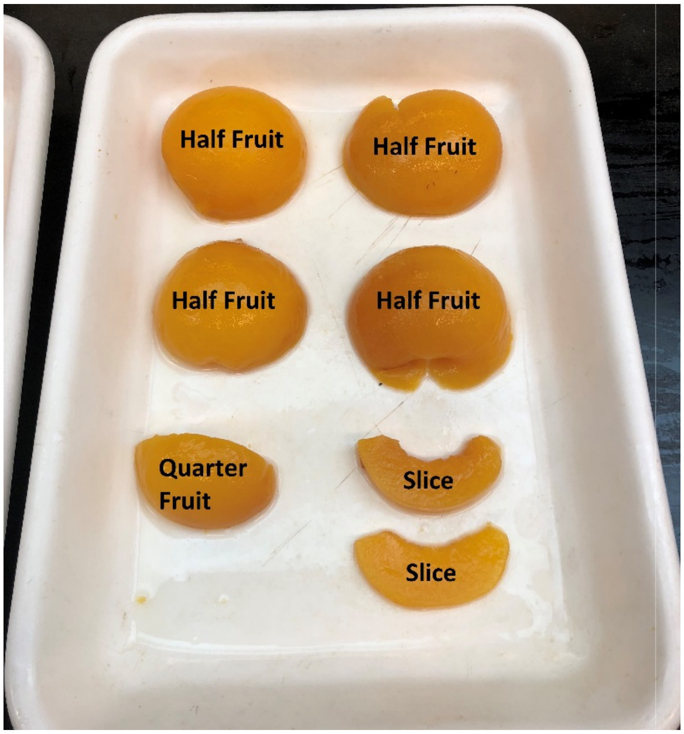


*Figure 9 Peach piece size scale used on the Cling Peaches for the post-canning evaluation.*

## 5.3 Conclusions

The results from our evaluations as displayed in Figure 5 show us that there is not a significant difference in the rate of injury between the two harvest methods. The bruising score for the two methods in the pre-peel evaluation were 1: Mechanical Harvest and 0.8: Control Harvest, while the scores in the post-peel evaluation were 1: Mechanical Harvest and 1: Control Harvest. Figure 5 also shows that there was not a large uptick in the number of punctures and scrapes in either of the two harvest methods between the first two evaluations. Because the fruit was harvested slightly over ripe any punctures or scrapes occurred usually reached past the skin surface and into the softer flesh. This meant they were visible in the both pre and post-peel evaluations.

Figure 6 and Figure 7 show the rate of browning between the two harvest methods after two months in cans. These figures show there was not any significant difference in browning between the two methods. Figure 9 shows the cans contained fruit pieces that were slightly smaller than the half and quarter fruit pieces we chose to focus on in our graphs. We decided not to include these pieces in our evaluations because they did not have enough surface area to provide a reliable visual of browning. The rate of browning in general is higher than would be normally expected in a commercial crop. This high rate is likely a result of harvesting over ripe peaches and the high rate of brown rot present in the field.

## 6. REFERENCES


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Project Title: Apple Rootstock Breeding Program Field Trails
Project Leader: Dr. Gennaro Fazio

**Project Summary**

The U.S. apple industry features 244,000 acres of orchards which produce 240M bushels each year with a farm gate worth of almost 4 billion dollars. Apple rootstocks are the foundation of a healthy and productive apple orchard. They are the interface between the scion and the soil, providing anchorage, water, nutrients, and disease protection that ultimately affect the productivity and sustainability of the orchard. Dwarfing and early bearing apple rootstocks provide unique advantages in fruit growing as they increase the efficiency of fruit production by making the orchard amenable to high density and automated or mechanically assisted operations. Most commercial dwarfing apple rootstocks being used by the U.S. industry are susceptible to devastating diseases (fire blight, apple replant disease, viruses), can be intolerant to other abiotic stresses (cold, drought, nutrient deficiencies, poor water quality) and may not be physiologically compatible with existing grafted scion varieties. This research project concerns breeding and evaluation of improved apple rootstocks and developing an understanding of the genetic and physiological components of apple rootstock traits. In cooperation with other USDA units, universities, and private concerns, the project aims to develop and release improved apple rootstocks and apply genomic, phenomic and bio-informatic tools for marker assisted breeding of apple rootstocks while leveraging discoveries in plant nutrition and root morphology. Research work in greenhouse, laboratory, nursery, and field plots, whether located at the PGRU or at cooperators' facilities, will be used to evaluate the characteristics of interest and examine new rootstock selections for commercial adaptation. The project utilizes cost efficient state of the art technologies to understand how rootstocks can make the orchard more productive and apply such knowledge to develop improved rootstocks. This research impacts all U.S. apple producing regions, with the potential to improve productivity, safety and survivability of apple orchards by 10% to 20% when new rootstock technologies are implemented, and increasing labor efficiency by enabling mechanization of cultural practices.

California Field Trials

In April of 2019, Dr. Gennaro Fazio from the Plant Genetic Resources Unit at USDA-Agricultural Research Service based at Cornell University, visited the CAC Board of Directors. The purpose of his visit was to discuss the potential opportunities for the California apple industry to explore the use of Geneva rootstocks. As a result of this visit, Dr. Fazio, reaching out to the industry with an opportunity to plant field trials utilizing new rootstocks in California. With the assistance and collaboration of Sierra Gold, the Apple Rootstock Breeding Program was able to secure roughly 840 trees to be planted at two different locations in California. The trees will be both Granny Smith and Gala varieties as these are familiar to the California industry at this point in time. The trials will begin in the spring of 2020, and a report of the trial results will be disseminated to the industry accordingly.

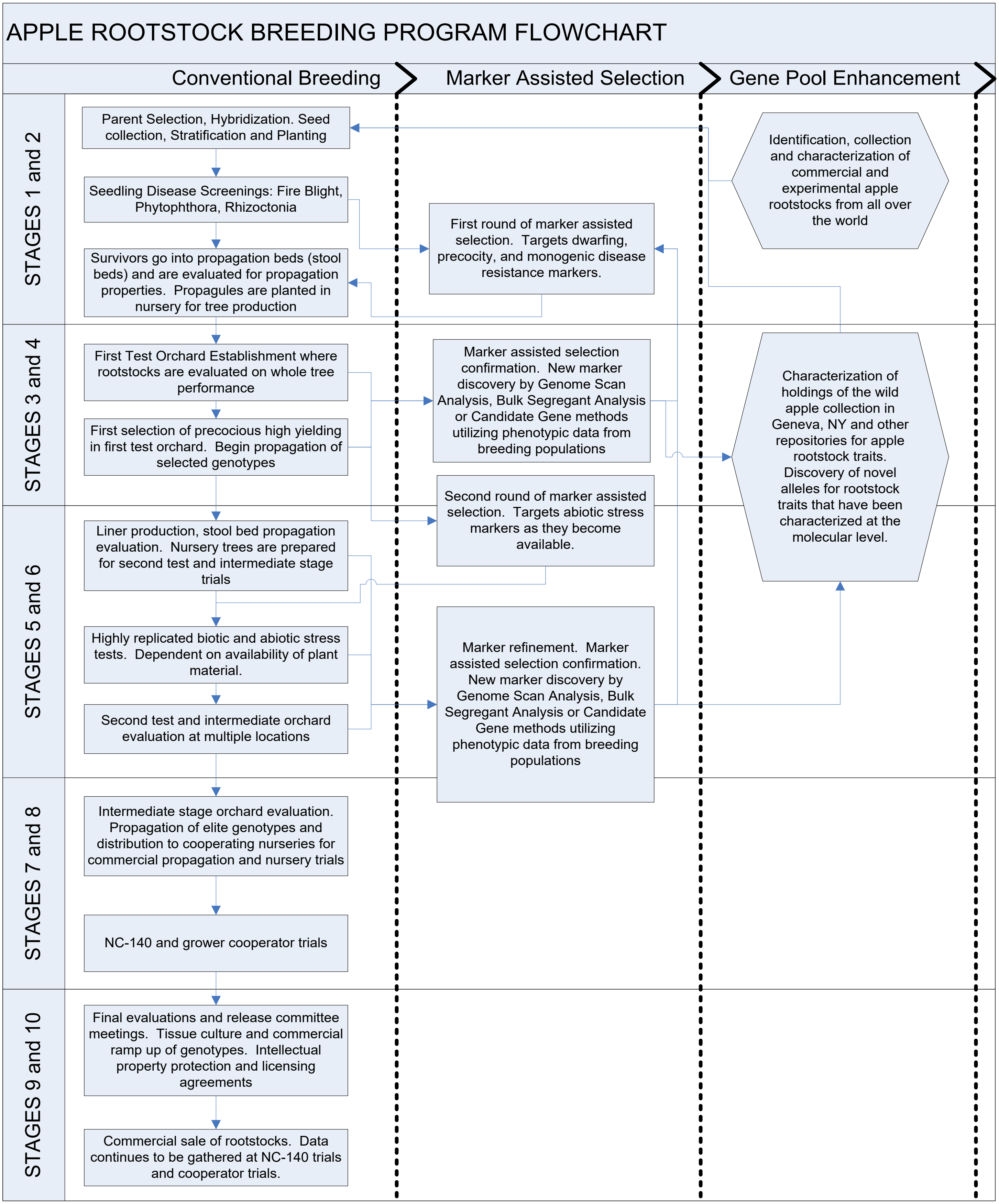



Figure 1. The breeding program has plants in all stages of breeding

## Objectives

The Geneva® Apple Rootstock Breeding Program has a good track record of providing superior apple rootstock genotypes that are more productive and disease resistant than currently available rootstocks for the U.S. and world apple industry. The program will pursue this by means of best affordable technology available, including novel methods of high throughput phenotyping, genomic and bioinformatic tools.

- **Objective 1: Develop and release improved apple rootstocks by leveraging advances in marker assisted breeding, including construction of genetic maps, establishing trait associations, gene discovery for important rootstock traits (dwarfing, early bearing, yield efficient, fire blight resistant), and screening for novel alleles for important rootstock traits. [NP301, C1, PS1A, PS1B]**
    - Sub-objective 1A *Perform all breeding and evaluation stages involved in the 15-30 year process (timeline depending on intensity of phenotyping and need to fast-track) of developing new rootstocks with the assistance of recently developed breeding tools, such as high throughput phenotyping and marker-assisted breeding.*
    - Sub-objective 1B *Identify and characterize novel germplasm, genes, alleles and trait loci through quantitative trait analyses leveraging new genetic-physical maps.*
- **Objective 2: Identify and dissect important rootstock traits that modify gene activity in the scion, toward enhancing drought tolerance, tree architecture, propagation by nurseries, root growth and physiology, nutrient use efficiency, and disease resistance; incorporate this knowledge into breeding and selection protocols. [NP301, C3, PS3A; C1, PS1A]**
    - Sub-objective 2A *Identify components of rootstock induced traits that modify gene expression and metabolic/physiological profiles of grafted scions to increase tolerance to abiotic stresses, improve fruit quality and storability, increase tree productivity, disease resistance and nutrient use efficiency.*
    - Sub-objective 2B *Validate relationships between trait components and overall apple tree performance in different rootstock-scion combinations and incorporate new knowledge into breeding and selection protocols.*

**Need for Research**

**Description of problem to be solved:**

The United States has 7,500 apple producers who, collectively, grow 240 million bushels of apples on average each year on 322 thousand total acres of land. The farm-gate revenue, or wholesale value, of the U.S. apple crop annually is close to $4 billion, with a predicted additional $14 billion related downstream economic activity each year (U.S. Apple Statistics). Members of the U.S. apple industry and industry groups (Washington Tree Fruit Research Commission – WTFRC, New York Apple Research and Development Board - NYARDP, U.S. Apple, etc.) have prioritized national and localized research needs that address problem areas identified by stakeholders. For example research needs in the "critical" and "high priority" for 2017 by the WTFRC included "soil health" and "improved rootstock and scion genetics", highlighting the importance of new rootstock technologies to promote sustainability, efficiency and increased productivity for their industry (http://www.treefruitresearch.com/images/2017_apple_hort_postharvest_priority_list.pdf ). Secondary to the choice of a scion variety, the choice of rootstock is perhaps the most important orchard establishment decision growers make because rootstocks affect productivity, fruit quality, orchard longevity, mechanization and many other aspects of apple production. Another aspect that was not evident until recent experiments is that there is a scion by rootstock interaction that can be leveraged to make the system more (or less) efficient i.e. the scion variety Honeycrisp produces more good quality apples with G.890 as a rootstock than G.210. Understanding the underpinnings of that interaction and designing new rootstocks that can be classified or localized to a specific environment and scion variety is very important to apple growers. The scion-rootstock-environment interaction begins at the soil-root interface where water, soil properties, nutrients and rhizospheric biota mingle with rootstock genetics to affect whole tree traits like drought tolerance, nutrient uptake efficiency, anchorage, and replant disease disorder etc. The interaction continues as the rootstock transcriptome, metabolome, phytohormone apparatus sends and receive signals from the scion – with the graft union as the interface between the two genotypes. More research is needed to understand those interactions and produce improved rootstocks that increase the profitability of the apple industry.

**Relevance to ARS National Program Action Plan:**
Apple growers require improved, economically and environmentally sustainable production systems to compete in the international fruit market. They are doing this by establishing high-density orchards of high-value cultivars. The apple rootstock determines many key aspects of tree performance, including tree size, productivity, fruit quality, nutrient uptake efficiency, pest resistance, stress tolerance, and ultimately profitability. New, improved rootstocks that incorporate improvements in biotic and abiotic stress tolerance/resistance traits are essential to grower profitability because in modern orchards, rootstocks are subjected to numerous biotic and abiotic stresses – rhizospheric pathogens, temperature, water availability, soil pH, and fertility. These stresses end up affecting not only tree productivity, but also the quality of fruit being harvested. The returns from high-density plantings far exceed those of low-density plantings. However, the initial investment may cost 10 times more for high-density plantings than low-density plantings, thus greatly enhancing economic risk. A key component of high-density apple production is the rootstock. The rootstock can induce early cropping, thus allowing close plant spacings. It is critical to develop more rapid means of screening potential rootstock candidates for susceptibility to stresses, to understand how different rootstocks respond to biotic and abiotic stresses, and to develop recommendations for the use of particular rootstocks under changing orchard conditions and production practices. Understanding factors contributing to apple root physiology – stress tolerance, nutrition, and growth related gene networks is vital. Knowledge of the physiological mechanisms that underlie these responses will allow for the development of genetic maps, molecular markers for target traits, new marker assisted breeding strategies, cultural practices, and ultimately practical means for mitigating various stresses for industry.
The proposed research is relevant to the NP 301 Action Plan, Component 1 – Crop Genetic Improvement; Problem Statement 1A: Trait discovery, analysis, and superior breeding methods; Problem Statement 1B: New crops, new varieties, and enhanced germplasm with superior traits; and to Component 3 – Crop Biological and Molecular Processes; Problem Statement 3A: Fundamental knowledge of plant biological and molecular processes.

**Potential benefits expected from attaining objectives –**
**NP 301 Action Plan Anticipated Products to which the project will contribute -**

- 1. Higher yielding plants.
- 2. Plants with resistance or tolerance to diseases and pests.
- 3. Plants tolerant to environmental changes or extremes.
- 4. Plants optimized for production efficiency.

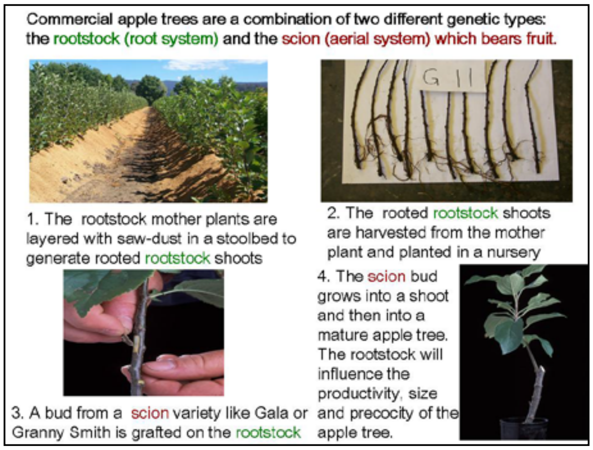
**Specific project products and/or outcomes**:

- New apple rootstock varieties with superior performance with regards to dwarfing, productivity and disease resistance.
- New understanding about genetic effects of apple rootstock on several whole tree health traits including tolerance to replant disease, nutrient absorption and translocation.
- New understanding about the application of tree architecture modifying rootstocks to make the orchard/nursery more amenable to mechanized operations.
- Incorporation of new alleles/traits in the apple rootstock breeding pool. Identification and characterization of new gene pools for apple rootstock traits.

- Genetic maps, robust, haplotype-specific molecular markers linked to important traits, and new marker assisted breeding protocols.
- Generation of mass-gene expression profiles of rootstocks in breeding populations and integration of expression profiles with marker assisted breeding.

**Customers of the research and their involvement**

Our customers are all apple growers, especially those in the regions affected by fire blight (Northeast, Midwest, Northwest U.S.) and growers who plant in soil that is symptomatic for Apple Replant Disease. These customers include small, medium and large conventional and organic fruit growing companies – growers like Jennifer Crist and Jim Bittner in New York and Mike Wittenbach in Michigan who have planted field trials of Geneva® rootstocks because of their need to find better stocks that are resistant to fire blight and that will perform well under organic management (Singer Farms -Bittner); growers near the tri-city area in Washington where they witnessed increased incidence of fire blight in the last five years; and growers in the Yakima (WA) who will need to replant a quarter of older orchards in the next 10 years while virgin land, optimal for apple orchards, is becoming rare in the same area, leaving no alternative to replanting on previous orchard sites needing fumigation with harmful chemicals. Another customer group is made up of organic apple growers and growers participating in integrated pest management like Stemilt Growers Inc., the largest multiple apple variety shipper in the US and the largest organic apple grower in the state of Washington. Two other important customer groups are apple growers planting high density orchard systems and nurseries supplying North America that specialize in the production of apple rootstock liners and finished apple trees, like Richard and Brett Adams of Willow Drive Nurseries (Ephrata, WA), who are propagating test rootstocks for research trials in the US, Devin Cooper, owner of Willamette Nurseries (Canby, OR), Brett Smith of Treco Nursery (Woodburn, OR), Cliff Beumel of Sierra Gold Nurseries (Yuba City, CA), and Todd Cameron of Cameron Nurseries (Quincy, WA) who are among the several nursery operators that are propagating Geneva® rootstocks and selling liners or finished trees to growers everywhere in the US. Additional customers include international apple nurseries and growers that have found value in adopting superior apple rootstock varieties produced by this program.



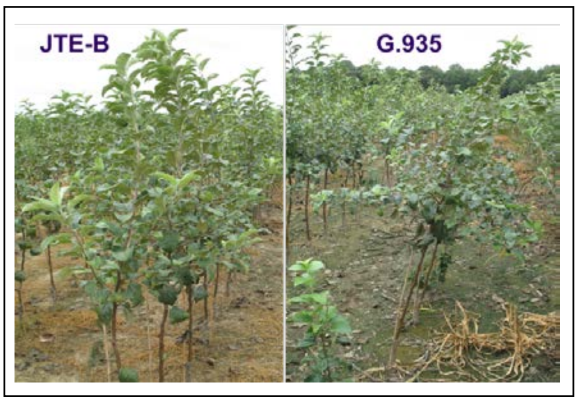




Figure 3. Comparison of nursery tree architecture featuring a flat branching rootstock, G.935 (right), versus an upright branching rootstock (JTE-B).

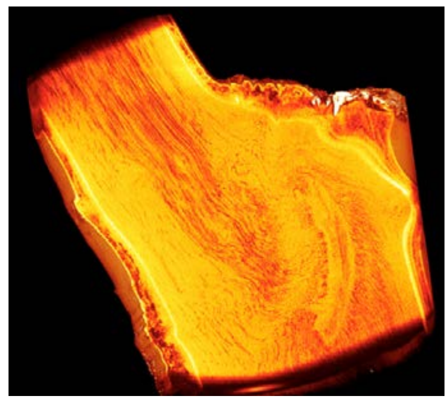
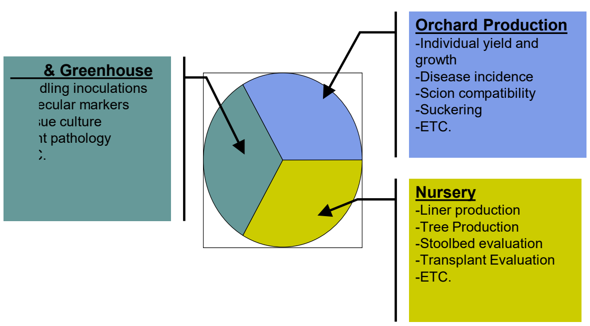


Figure 4. Micro CT scan of a graft union of Honeycrisp on G.41 showing the region where the bud was placed and the unorganized formation of some vessels that may contribute to graft weakness.




igure 5. Activities of the apple rootstock breeding program. aboratory, orchard and nursery components are essential for he success of the program.

able 1. Selection traits for breeding apple rootstocks. These raits are sometimes evaluated at different locations by the nany collaborators of the apple rootstock program.

| | YEARS | |
|---|---|---|
| **Fire Blight resistance** | 1 or 7 | Greenhouse/Field |
| Phytopthora resistance | 1 | Greenhouse |
| **Replant Disease Complex** | 1 or 7 | Greenhouse/field |
| Wholly apple aphid res. | 1-5 | Greenhouse/field |
| Juvenility nursery - Spines | 3-4 | Field/Stoolbed |
| Stoolbed rooting | 3-4 | Field/Stoolbed |
| Growth habit - Brittleness | 3-4 | Field/Stoolbed |
| Dwarfing | 8-12 | Orchard |
| Precocity | 8 | Orchard |
| Suckering | 8 | Orchard |
| Yield – Biennial bearing | 12 | Orchard |
| Cold hardiness | 15 | Orchard |
| Drought tolerance | 4 | Orchard |
| Graft union compatibility | 5 | Orchard |

**Scientific Background**

**History and foundation germplasm** - The foundations of a productive and healthy orchard are the rootstocks that provide anchorage, water and nutrients essential to the above- ground portions of the trees. The utilization of composite trees has increased the efficiency of breeding productive apple trees by dividing the selection of scion traits and rootstock traits into two genetically (and functionally) different specimens, which are then brought together through grafting. The art and science of grafting scions onto rootstocks spans several millennia; it is thought that it was used initially to aid in the clonal propagation of desirable scion varieties for fruit and nut production (Janick, 2005). In these millennia, it is likely that very little attention was dedicated to the selection of a particular rootstock chosen for its properties (ease of propagation) and the properties it imparted to the scion (Tukey, 1964; Rom and Carlson, 1987; Webster, 2003; Webster and Wertheim, 2003). Clonal selection and the beginning of the science of rootstocks seems to have originated in the latter half of the last millennia, where at least for apple, certain rootstock clonal selections were identified to impart unique productivity and architectural properties (early bearing and dwarfing) onto the grafted scion variety (Monceau, 1768). It is very likely that these properties existed or were selected directly on own-rooted trees first as these trees were early bearing, inherently dwarfed and production of fruit from these curious apple plants was early and abundant compared to seedling trees (Loudon, 1822). The combination of small architecture and productivity is optimal for cultivation in fruiting gardens typical of monasteries, aristocratic and wealthy middle-class dwellings (Rivers, 1866), where the 'Paradise' apple, 'Jaune de Metz' (Lindley, 1828) otherwise known as Malling 9 (and relatives) could make grafted scions dwarfed, becoming popular in central Europe for making composite dwarfed trees (Hatton, 1917). Scientists at the East Malling Research Station in the United Kingdom, collected many clonal rootstocks from around Europe and painstakingly characterized each of them eliminated duplicates and established foundation material of rootstocks named 'Malling 1-16' (Hatton, 1919; 1920). Rootstock "Malling 9' (M.9) and its sport mutations became the primary rootstock that fueled the green revolution of dwarfed apple orchards that occurred in the twentieth century in many apple production regions of the world. Narrow crosses among the Malling rootstocks resulted in two widely used rootstocks: Malling 26 (M.26) and Malling 27 (M.27) that have improved propagability, and different forms of the early bearing and dwarfing effects. Most of the dwarfing founding germplasm was interrelated and had a narrow genetic base (Oraguzie et al., 2005; Gharghani et al., 2009), suggesting the need to introduce new forms of disease resistance and improvement on other horticultural characteristics through wide crosses with germplasm that exhibited the desired phenotypes (Aldwinckle et al., 1999; Momol et al., 1999; Forsline et al., 2002). The results of these wide crosses have produced a series of rootstocks that combine disease and insect resistance with productivity, and represent the second generation of rootstock technologies applied worldwide (Fischer, 1991; Wertheim, 1998; Fischer et al., 2000). The apple rootstock breeding program operated in Geneva, NY is the only one that has commercial deployment of results from these wide crosses. This breeding program has operated in Geneva, NY since 1968 by Cornell University Geneva Campus and joint with the U.S. Department of Agriculture Agricultural Research Service since 1998 (Johnson et al. 2001; Fazio et al. 2015b). This program produced the Geneva® series of apple rootstocks by crossing germplasm that complemented the weaknesses of the Malling germplasm (susceptibility to fire blight, woolly apple aphids, crown rots) and systematically crossed such germplasm with all available dwarfing, precocious rootstock germplasm available to the program (Gardner et al. 1980a, b). The parent Robusta 5 became the source of resistance to fire blight and woolly apple aphids (Aldwinckle et al. 1976; Aldwinckle and Lamb 1978; Cummins et al. 1983). Several novel traits have been identified in the Geneva® germplasm including induction of flat branching (or open tree architecture), increased nutrient concentration, and induction of bud-break in low chilling environments (Fazio and Robinson 2008; Fazio et al. 2012, 2013; Jensen et al. 2012). The Geneva® breeding program continues to make new crosses to improve tolerance to drought and other biotic and abiotic stresses that can be ameliorated in apple rootstocks. (Fazio et al. 2015b; Shin et al. 2016; Tworkoski and Fazio 2016; Tworkoski et al. 2016). As our understanding of physiology of apple trees, both at the whole tree level and at the cellular level, has increased, so has the understanding of how and what scion properties are modulated by rootstocks, thus increasing the target traits that may be selected to improve whole tree performance by improving rootstock performance (Fazio and Mazzola, 2004). Improving rootstock performance involves two sets of very different types of traits: the inherent apple rootstock traits (rooting for propagation, lack of spines and burr knots, resistance to root pathogens, cold hardiness, etc.) which deal with the interaction between rootstocks and the environment, and scion traits that are modulated by rootstocks (tree architecture, productivity, etc.) that represent the interaction between rootstocks and scions.

**Breeding methods** -Breeding apple rootstocks can be a very lengthy process (Johnson et al., 2001a); there are two ways to accelerate the process: the application of marker- assisted breeding (MAB) in the pipeline and/or the intensification of later stages of field testing (Fazio et al., 2015b). The first aims to eliminate substandard germplasm (non-precocious, non-dwarfing, susceptible to diseases, etc.) from the parental and progeny pools via the development and application of robust diagnostic markers. The second is to increase the number of clonal plants tested for each elite genotype and subject them to multiple phenotyping tests and environments that represent production regions. The theoretical benefits from the application of marker technologies to breeding have been reported in publications (Bus et al., 2000; Fazio et al., 2003; Antanaviciute et al., 2012; Bassett et al., 2015). In 2011 the USDA- ARS apple rootstock breeding program located conducted an internal analysis of the economic impact of applying molecular markers in the breeding program by itemizing the cost per genotype for each stage of selection. A detailed description of the rootstock breeding program stages can be found in Fazio et al. (2015b). Briefly: stages 1 and 2 deal with parent selection, crossing, culling seedlings with disease inoculations and propagation of survivors; stages 3 and 4 deal with the establishment of plants as rootstocks in field orchards and propagation beds (see figure Fig. 1); stage 5 includes the evaluation of propagation beds and replicated tests on biotic and abiotic resistance. Stages 6-–7 are secondary highly replicated tests and stages 8-–10 deal with pre-commercial testing with multiple varieties and multiple locations. The Geneva breeding program elected to conduct the first round of MAB before stage 3, which involves the initial propagation of plants surviving Phytophthora root rot and fire blight screens. The cost of genotyping with two markers including DNA extraction and labor was about $10 per seedling. The cost to phenotype each seedling for dwarfing and precocity during stage 3 (9 years of evaluation) in 2010 dollars was $15.40/year for 9 years = $138. The cost savings by culling non-dwarfing individuals was significant, and in 2012 we were able to plant 2 orchard rows of well- replicated, high- density first- test orchard instead of the 12 previously planted.

**Scion traits affected by rootstocks** - Until recently, the number of traits that were recognized to be modulated by apple rootstocks was pretty small: tree vigor, early bearing, and water use. This list has been expanded to new architecture components such as canopy shape and bud break (sylleptic branching), and effects on fruit size and quality, on disease resistance and on nutrient availability in the scion. Perhaps the biggest breakthrough in our understanding of rootstock effects on scions is the study that monitored gene expression changes in scion tissue by different apple rootstocks (Jensen et al., 2003; Jensen et al., 2010; Jensen et al., 2011; Jensen et al., 2012). At the cellular level, signals sent from the root system of different genotypes to the scion can change the expression levels of genes, which in turn change the composition of proteins and related metabolic processes and compounds in the scion. While there are no experiments in apple that have described the opposite interaction, it is safe to assume that this dramatic change likely occurs as signaling from the scion affects the way roots behave and grow. The science behind understanding the issue of communication and affinity between scion and rootstock seems to be in its infancy and has a lot of potential as the concept of “designer rootstocks” gets more traction in the industry.

***Tree vigor*** -The reduction in tree vigor (Figure 2) is perhaps the most important trait imparted by apple rootstocks to the grafted scion (Tukey, 1964). It is imparted to the scion as an early termination of overall season growth (Seleznyova et al., 2008). The benefits due to this trait in modern orchards are enormous and range from increased efficiency in picking and tree management operations, including mechanization, to the decrease of pesticide inputs, ladder accidents, and other ergonomic issues (Groot, 1997a; Groot, 1997,b; Masseron and Roche, 1999; Robinson et al., 2007; James and Middleton, 2011). At the physiological level, the dwarfing trait has increased the effective light interception and partition to fruit production in the orchard and increased the production per unit area by at least 30% when compared to non-dwarfing rootstocks (Brown et al., 1985; Strong and Miller Azarenko, 1991; Atkinson et al., 1998). This means that for an industry worth $4 billion like the U.S. industry at least $ 900 million are a result of the efficiency gained through dwarfing rootstocks. While the genetic components to this trait have been described to be the interaction of two main loci (Fazio et al., 2014b) and perhaps additional modifying loci (Harrison et al., 2016, Foster et al. 2015) it is important to mention that this is a complex trait that has fairly big interaction components and that the total effect of these components results in the overall vigor of the tree. Therefore for any scion 'S', the vigor 'V' is equal to the inherent growth dynamic genetics of the scion 'Sg', plus the dwarfing genetic components of the rootstock 'Rg', plus their interaction, plus the interaction of the whole composite tree with environmental effects 'E' such as fertility, water availability, diseases, soil type, soil pH, and soil type, or orchard management, weed competition, and the like, so that when scion vigor is measured, the genetic components of dwarfing rootstocks are only a part of the equation. This is exemplified by observing the effect of stunting caused by soil-borne replant disease, which has a similar effect to the dwarfing loci in apple and sometimes confuses the estimation of vigor potential of a rootstock (Auvil et al. 2011).

While several architectural dwarfs have been identified in domesticated and wild apple populations (Fazio et al., 2009a; Fazio et al., 2014a), this material has not produced commercially viable rootstocks or has not been tested for similarity to the dwarfing characters offered by the alleles contained in M.9, M.8, M.13 and other Malling rootstocks belonging to the initial set selected in East Malling. The dwarfing trait has been shown to be highly heritable, modulated mainly by the combination of alleles of locus Dw1 found on chromosome 5 (Rusholme et al., 2004; Pilcher et al., 2008) and locus Dw2 found on chromosome 11 (Fazio et al., 2014b). Models that take into account some or all combinatorial allelic effects of these two loci have been able to explain upwards of 80% of the genotypic variation for dwarfing (Foster et al., 2015). The two loci interact with each other and do not necessarily seem to be additive, meaning that the lack of one dwarfing locus effect in the model negates the effect of the other. Several physiological models based on phenotypic observation have hypothesized the involvement of hormone signaling (Zhang et al., 2015; Tworkoski and Fazio, 2016), graft union anatomy (Tworkoski and Miller, 2007; Tworkoski and Fazio, 2011), hydraulic conductivity (Atkinson et al., 2003; Cohen et al., 2007), dry matter partitioning to fruit production, or a combination of these (van Hooijdonk et al., 2011), while the underlying causative genes are still largely unknown. Evaluation of this trait for breeding still requires a lengthy period of 7-–10 years for the first observation and perhaps another 10-–12 years for multi-location trials with multiple scions. As mentioned in the beginning of this section, multiple field trials are needed to evaluate rootstock interactions with different scions and environmental factors.

***Induction of early bearing in scions*** - Apple seedlings planted on their own roots experience a juvenile period anywhere from 4-–7 years before they reach sexual maturity and bloom and fruit (Visser, 1967). Some dwarfing rootstocks have the ability to induce early bearing or reduce the juvenile period to 2 years in extreme cases (Visser and Schaap, 1967; Visser, 1973). Early bearing is a major selection criterion for improved apple rootstocks because the intensive types of cultivation of apple require a quick return on investment (early production of apples) to offset the installation and infrastructure costs to build the orchard (Cummins et al., 1995; Robinson et al., 2007; Robinson et al., 2011). The genetic loci underlying the rootstock- induced trait 'early bearing' were first described by Fazio et al. (2014), who identified two loci, Eb1 and Eb2, that roughly co-located with Dw1 and Dw2, perhaps indicating that the two traits may be physiologically and genetically interconnected. Several studies have described the rootstock-induced partitioning effect of photosynthate into sexual (fruit) and vegetative portions of the tree (Seleznyova et al., 2008), comparing the effects of different rootstocks (Marini et al., 2006a; Autio et al., 2011b; Autio et al., 2011c), crop loads on tree growth (Marini et al., 2012), productivity, and bienniality (Marini et al., 2013). However, there is paucity in the literature about the causative elements for these rootstock effects. Breeding for this trait requires field evaluation for four years for the first observation in a replicated experimental orchard and then an additional 5 years in multi-location, multi-scion trials. Visser (1967) showed that scions with reduced juvenility also seemed to be more productive when grafted on M.9

dwarfing rootstocks, indicating the possibility of an inherent scion effect on early bearing and the need to test this scion-–rootstock interaction in replicated trials.
***Induction of sylleptic branching in the nursery and other architectural changes*** - Early and abundant fruit production is related to the number of flowering buds produced in the nursery phase and early establishment of the tree in the orchard (Ferree and Rhodus, 1987; Robinson et al., 1991a; Robinson et al., 1991,b; Theron et al., 2000). This number can be influenced not only by the early bearing effects of the rootstocks discussed previously, but also by the ability of the rootstocks to produce prolific sylleptic branching (feathers on a nursery tree) in the nursery and later in the orchard. Early yield has been associated with nursery tree caliper , tree height, and number of feathers. Rootstocks with wider genetic diversity than M.9 and Budagovsky 9 (B.9) have been shown to influence the production of sylleptic branches and the formation of crotch angles, that produce trees with a more open (flatter branches) structure (Fazio and Robinson, 2008a; Fazio and Robinson, 2008,b). This characteristic is mostly observed in rootstocks developed by the Geneva, New York, breeding program, especially with rootstocks G.935, G.213 G.41 and G.214 (Figure 3). The strength of these effects vary with different scions and continue through the life of the tree in the orchard, as observed in the millions of trees planted on G.935 rootstock throughout the world. One additional characteristic that may be related to sylleptic branching is the ability of some rootstocks in the Geneva breeding program to induce bud break and flowering in low chill environments. This effect was observed in a highly replicated trial in Southern Brazil with ‘Gala’ grafted on three rootstocks (G.213, M.9 and, Marubakaido with M.9 interstem (an interstem is a section of the trunk grafted in between the rootstock and the scion usually made from a third rootstock variety to bridge incompatibility or leverage the qualities of the interstem to increase precocity of the whole tree) where it was observed that in Spring time flowering and bud break were 35% higher in trees with G.213 rootstocks, resulting in higher productivity of the trees (Francescatto, pers. comm.). Breeding for these characteristics requires a lot of time and effort as the effects are confounded by the interaction with the dwarfing potential of the rootstocks and the difficulty of measuring crotch angle and branch length of thousands of replicated nursery trees. Our understanding of the genetic effects underlying these traits is in its infancy as the trait was first described in 2007. It is likely that research and breeding efforts aimed at uncovering the genetic factors for these traits will lead to more productive apple trees.
***Propagation traits*** - Apple rootstocks can be clonally propagated by sterile in vitro methods, soft and hard wood cuttings (Bassuk and Howard, 1980), and by layer or stool cuttings (Adams, 2010). While efforts to breed rootstocks amenable to in vitro culture are virtually impossible due to the complexity of media and growing conditions, efforts to improve rooting ability in layering beds and cuttings although difficult may result in superior rooting genotypes. Breeding for nursery performance can be quite complicated as many factors influence apple rootstock performance in the different nursery phases and at times may conflict with field performance. A prime example of this is the fast and easy adventitious rooting trait, highly desired in the propagation phase but correlated with the development of burr knots in the orchard – a harmful trait in certain orchard environments especially where dogwood borers and other insect borers may be present (Bergh and Leskey, 2003). These difficulties can be overcome with improved nursery management practices developed for the establishment of new layer beds, that which include utilization of different propagation techniques like cuttings (Hansen, 1989; Deering, 1991) or micropropagation (Castillo et al., 2015; Geng et al., 2015), and the treatment with plant growth regulators such as prohexadione calcium in the nursery (Adams, 2010) to increase production of primary adventitious roots. The genetics of adventitious root formation have been investigated in the Geneva breeding program revealing a complex trait with low heritability. Therefore, while it may be possible to breed for rooting traits, the importance of these traits is dwarfed by the importance of low suckering and lack of burr knots in the orchard.
Another characteristic affected by the rootstock is graft compatibility. Historically, most problems that were blamed on compatibility turned out to be virus related (Cummins and Aldwinckle, 1983; Lana et al., 1983), however, certain rootstock/scion combinations under unspecified grafting and nursery management conditions have shown a tendency for weak graft unions in very young trees (Robinson et

al., 2003). Graft incompatibility can arise because of the disruption of normal healing between grafted tissues and can result in anatomical and physiological symptoms, biochemical and mechanical issues that lead to graft failure or tree death (Simons and Chu, 1983, 1985; Skene et al., 1983; Simons, 1985; Simons and Chu, 1985). While it is likely that the method of grafting (chip budding, whip -and- tongue grafting, and machine V grafting) (Hartmann et al., 1997) has an effect on healing and union strength at various stages in the nursery cycle, there may be plant- growth- regulator-related and metabolic- compound -related signals that prevent the formation of a strong graft union. Efforts to understand the ability of the rootstock/scion combination to generate enough connective tissue where they meet is underway in the Geneva breeding program through the use of X-Ray tomography (CAT Scans) shown in figure Fig. 4. Some nurseries report that large caliper stocks may not form as strong a graft union as small caliper stocks; therefore, a rootstock genotype that produces smaller caliper liners from the stool bed may be more suitable for nursery tree production.

***Drought tolerance -*** It is difficult to define drought tolerance without an objective reference or phenotype to measure and it is even more difficult to define in a rootstock independent of the scion- specific tolerance (Higgs and Jones, 1991; Virlet et al., 2015). The economic definition of drought tolerance (little or no loss of marketable fruit production) is different from some of the physiological definitions, which range from loss of photosynthetic activity (Massacci and Jones, 1990), to shoot and root growth under stress (Atkinson et al., 2000), to water use efficiency. Perhaps drought- tolerant rootstocks are of little value where irrigation water is available and relevant only in regions that utilize rainwater and may experience long stretches of drought. However, as climate changes and fresh water availability is threatened in traditional apple growing regions, the search for rootstocks that can thrive with less water is becoming more and more important (Ebel et al., 2001). It has long been recognized that there are differences in apple rootstock reaction to drought (Preston et al., 1972; Cummins and Aldwinckle, 1974; Ferree and Schmid, 1990), but those observations mostly dealt with spurious drought events and compared vigorous and non-vigorous types (Chandel and Chauhan, 1993; Fernandez et al., 1994). Decreased sensitivity to drought was attributed to 'Malling 9' rootstock when compared to 'Mark' (Fernandez et al., 1997) in a potted tree study. A comparison of hormonal drought response between M.9 and MM.111 rootstocks indicated that both rootstocks provided drought resistance but by mechanisms which appear to differ -– M.9 produces higher levels of abscisic acid (ABA) that may regulate stomatal opening while MM.111 possesses a more extensive root system (increased soil exploration index) (Tworkoski et al., 2016). Water use efficiency, defined as the ratio of biomass produced to the rate of transpiration, and decreased sensitivity to drought (Xiang et al., 1995; Bassett et al., 2011) has been described in wild apple populations indicating the possibility of using this descriptor as a selection method. Breeding for such a complex trait may be possible only at latter stages of selection as discernment of field-meaningful data requires experiments with high replication, special equipment to control water delivery and use, and very- high- density morphological and physiological measurements. Perhaps gain can be made by selection of components of the trait such as improved root morphology, plant growth regulator signals, and nutrient uptake once their effect is identified in breeding populations possessing all the other 'important' traits.

***Cold tolerance -*** Several rootstocks seem to be tolerant to the different types of cold events that can cause injury of cambial and root tissues (Embree, 1988). Damaging cold events can be quite different in their mode of action as mid-winter, events can have very different modes of action than late fall or spring cold events (Cline et al., 2012). Therefore, the methods used to evaluate sensitivity to differing cold injuring events need to address the physiological conditions specific to each event (Quamme et al., 1997; Moran et al., 2011a; Moran et al., 2011,b). Fluctuating temperatures in late fall, early winter and early spring are associated with hardening and de-hardening of tissues. This hardening and de-hardening process may have a strong genetic component (Forsline and Cummins, 1978), where a group of Malus rootstocks seem to have improved ability to be insensitive to such temperature fluctuations and remain dormant and cold-acclimated. Harvesting rootstock liners during these periods and subjecting them to increasingly low temperatures to show cambial damage is perhaps the most meaningful way to select cold hardy apple rootstocks. Observation of black-heart damage can also aid in the discernment of rootstock/scion combinations that are susceptible to mid-winter injury (Warmund and Slater, 1988; Warmund et al., 1996). Genes associated with cold response have been described for 'Gala' scions (Wisniewski et al., 2008), and similar genes may be found in apple rootstocks. However, the understanding of segregating factors that influence the different types of cold stress adaptation is virtually non-existent, making genetic or genomic-informed breeding impossible, and therefore selection relies entirely on highly replicated phenotyping.

***Root morphology and architecture -*** Phenotypic variation in the morphology of roots has been associated with increases in yield and tolerance to abiotic stresses in several crops (Sousa et al., 2012; Chimungu et al., 2014; Lynch et al., 2014; Burton et al., 2015; Zhan et al., 2015). Harnessing genetic and phenotypic variation in root morphology traits in apple rootstocks may improve productivity, tree size, drought tolerance, nutrient uptake, anchorage and other related whole tree functions (Eissenstat et al., 2001). Ample phenotypic variation has been characterized in wild Malus sieversii populations and within the Geneva apple rootstock breeding program where genetic factors for fine root formation (highly branched fine roots) have been mapped to chromosome 4 and 11 of the apple genome (Fazio et al., 2009b). Other traits that may be important to characterize may be the volume explored by the roots, the angle of the roots, the longevity of the roots and so on, etc., which are all traits that are difficult to phenotype and for which robust genetic markers may be extremely useful. In Geneva, New York , the apple rootstock breeding program measured several scion and root morphology characteristics of nursery trees of related (half- sibs) Malus sieversii seedlings which showed correlation between canopy volume/tree size and number of thick roots (0.38, $P < 0.001$), and a less pronounced correlation between tree size and root mass (0.25, $P < 0.001$), indicating a feedback loop between scion and root growth: the ability of the canopy to support the growth and expansion of a larger primary root system increased the vigor of young trees by their ability to produce root systems with strong primary hierarchy (Fazio et al., 2014a). Apple root systems vary in seasonal growth patterns (Eissenstat et al., 2006), which may affect their ability to forage for nutrients and water, and even colonization with beneficial mycorrhizae (Resendes et al., 2008). Root turnover rates may also play a significant role in tree nutrition and productivity as well as disease resistance or evasion as demonstrated by experiments that utilized replant -tolerant rootstocks from the Geneva breeding program (Atucha et al., 2013; Emmett et al., 2014). While these root traits can be targeted for marker assisted breeding (MAB), the understanding of genes, gene expression patterns and physiological attributes associated with these traits in rootstocks is limited compared to our understating of scion traits; therefore, more research is needed to understand these traits before they become the subject of selection based on genetic markers. The program is currently leveraging aeroponic systems (Appendix B figures 1-3) and mini-rhizotrons to phenotype apple root systems.

***Nutrient uptake -*** Another set of root -related traits deals with the genetic variation and inheritance of absorption and translocation of macro- and micronutrients by the rootstock to the scion (Tukey et al., 1962). Rootstocks have been shown to vary significantly with regards to their intrinsic ability to forage for nutrients as well as transfer them up to various sinks in the scion, including fruit, perhaps affecting organoleptic, post-harvest qualities of the fruit and disease resistance (Lockard, 1976; Westwood and Bjornstad, 1980; Om and Pathak, 1983; West and Young, 1988; Chandel and Chauhan, 1990; Rom et al., 1991; Sloan et al., 1996; Chun and Chun, 2004; Kim et al., 2004). Transgenic, cisgenic, or conventional breeding approaches have been suggested to increase nutrient uptake of minerals such as zinc to improve productivity of the orchard (Swietlik et al., 2007). Most research on nutrient uptake by apple rootstocks has focused on developing the best management practices for nutrient application on a genetically restricted set of rootstocks, and it was not until a large set of genetically diverse rootstocks were observed in different soils and pH treatments that the physiological diversity of apple roots was revealed (Fazio et al., 2012). The analysis of scion nutrient concentration in leaves and fruit in several rootstock field trials in New York State have indicated the possibility that specific rootstocks may affect fruit quality of Honeycrisp apples showing that certain rootstocks are able to transfer higher calcium levels to the fruit and that the calcium-linked disorders typical of Honeycrisp are a result of scion-specific intrinsic challenges in the movement of calcium into the fruit (Fazio et al., 2015a). Investigation of the inheritance of nutrient uptake and translocation in a full- sib population of apple rootstocks revealed quantitative trait loci (QTL) influencing scion leaf mineral concentrations of potassium (K), sodium (Na), phosphorus (P), calcium (Ca), zinc (Zn), magnesium (Mg) and molybdenum (Mo), with the most significant ones on chromosome 5 for potassium, chromosome 17 for sodium and lower significance QTLs for calcium, copper, zinc, and phosphorous (Fazio et al., 2013). Concentrations of some nutrients were highly correlated (K and P, S and P), indicating common nodes in the networked pathway that takes nutrients from the soil through the rootstocks to diverse sinks in the scion (Neilsen and Havipson, 2014). The very different mechanisms (interaction with soil biota, active and passive transport, vessel composition and size, etc.) that impact absorption and transport and the fact that crop load and irrigation can also influence mineral concentrations (Neilsen et al., 2015) makes these traits difficult to improve without the aid of a robust understanding of molecular genetic factors involved. Modeling those factors to achieve a particular balance of nutrients in selected scions is therefore very complicated.

**Disease and pest resistance -** Commercial application of improved disease and insect resistance can be observed in the Geneva, New York, breeding program. Since its inception, the program focused on developing apple rootstocks resistant to fire blight, a North American disease caused by Erwinia amylovora while maintaining the resistance to crown and root rot caused by Phytophthora cactorum (Aldwinckle et al., 1972; Gardner, 1977; Gardner et al., 1980). This effort over three decades produced rootstocks that are not only resistant to fire blight and crown rot, but that are tolerant to the replant disease complex, and are also resistant to wooly apple aphids WAA (*Eriosoma lanigerum*).

***Resistance to fire blight***- Fire blight is a devastating disease caused by the anaerobic, gram-negative bacterium *Erwinia amylovora*, which causes visible symptoms in blossoms, green tissues, fruit and some woody tissues of apple scions and rootstocks. While this disease seems to have originated in the Eastern part of North America, it has now spread to most of the apple growing regions of the world. Rootstock blight on susceptible rootstocks (M.9, M.27 and M.26) can be devastating as the infection results in girdling and death of the rootstock shank eventually killing the whole tree – entire orchards and millions of trees have been destroyed because of rootstock blight. While spraying antibiotics like Streptomycin can alleviate the onset of rootstock blight, genetic resistance of the rootstock is the best preventive treatment. Rootstock resistance to E. amylovora is found in several wild apple species and these have been utilized to breed a new series of fire blight -resistant rootstocks. There seem to be two main types of resistance in apple rootstock: a multi-genic type similar to that is found in Malus robusta 'Robusta 5' where green tissues and flowers are not affected by the bacterium (Aldwinckle et al., 1974b; Cummins and Aldwinckle, 1974) and an ontogenic type of resistance found in Budagovsky 9 (B.9) rootstock where the green tissues are severely affected, but two- year- old and older wood seems not to react to the bacteria (Russo et al., 2008). Genetic inheritance of the 'Robusta 5' type of resistance has been described as having a strain- specific component on chromosome 3 identified as a gene belonging to the NBS-LRR class of resistance genes (Fahrentrapp et al., 2013; Broggini et al., 2014; Kost et al., 2015) and other minor QTLs on linkage groups 5, 7, 11, and 14, which do not seem to be strain- specific detected in a non-rootstock population ('Idared' x 'Robusta 5') (Wohner et al., 2014). Another locus that is non -strain specific was discovered on linkage group 7 in a rootstock population derived from a cross between 'Ottawa 3' and 'Robusta 5' (Gardiner et al., 2012). Cis-genic approaches with the LG03 gene proved only partially successful, suggesting a more complex pathway of resistance than just one gene recognition of the pathogen (Kost et al., 2015).

***Replant disease complex -*** The specific apple replant disease complex is a syndrome observed as stunting and poor growth of young apple trees planted in soil that was previously planted with an apple or pear orchard. This complex disease causes major production losses throughout the life of the orchard. The main causative agents implicated in this syndrome are *Cylindrocarpon destructans, Phytophthora cactorum, Pythium spp., Rhizoctonia solani* and various pathogenic nematodes (Mazzola, 1998). The occurrence of one or more of these agents will affect the severity of the syndrome and may explain some of the site -to- site variation observed in replant land. This is one of the major problems faced by orchardists as virgin land becomes more rare, major infrastructure investments (hail nets, irrigation, etc.) become more prevalent and require a 'replant -in- place' type of renewal of the orchard and as fumigation chemistries are restricted by environmental laws (Auvil et al., 2011). The removal of the old orchard leaves a major pathogen load in the soil, which overwhelms the young root system of nursery trees. Fumigation treatments (Methyl Bromide, Chloropicrin, and Nematicides) seem to be effective for less than a year as the pathogens implicated in this disease quickly recolonize the sterile soil, and fallow treatments (undesirable because they leave the land in an unproductive state) have shown mixed results, with replant symptoms sometimes appearing even after 4 years of fallow (Leinfelder and Merwin, 2006). Alternative treatments like seed meal amendments, fertilizers, compost teas, and solarization have been proposed and are in various phases of research and development (Utkhede, 1999; Utkhede and Smith, 2000; Mazzola and Mullinix, 2005; Mazzola and Manici, 2012). In addition to the combination of pathogens involved in each orchard, factors like soil type, climate and other edaphic conditions seem to affect the severity of the complex, making it difficult to diagnose (Fazio et al., 2012). The effects of the disease complex are usually measured by comparing the growth of the same rootstock in sterile soil (pasteurization or chemical treatment) to a biologically active soil collected from the rhizosphere of the old orchard (Leinfelder et al., 2004; Rumberger et al., 2004; Yao et al., 2006a). A comprehensive study of multiple rootstock accessions and Malus species indicated that there was sufficient phenotypic diversity to enable growth in non-pasteurized soil (Isutsa and Merwin, 2000); however, the only reported commercially applicable genetic tolerance to the replant disease complex seems to be derived from progeny of 'Robusta 5' and other wild apple species. Certain root genotypes have been reported to promote unique types of microbial communities, indicating a specificity or perhaps a pseudo- symbiotic effect of specific root systems that defeat the presence of pathogenic microbes (Yao et al., 2006b; Rumberger et al., 2007; St. Laurent et al., 2010). Breeding and selection for Phytophthora resistance is performed by inoculating young seedlings (Aldwinckle et al., 1974a). New studies leveraging Next-Generation sequencing of Pythium challenged rootstock seedlings show upregulation of disease resistance- related pathways in resistant plant material indicating the possibility to select for specific resistance to Pythium components of replant disease (Shin et al., 2016). The placement of several apple rootstocks and breeding populations in sterile culture (micropropagation) has enabled identification of separate genetic effects of resistance to the individual replant components, as these rootstocks were inoculated with cultures of Rhizoctonia species and Pythium species independently. While this set of experiments is still ongoing (Zhu, personal communication), preliminary reports indicate segregation of QTLs affecting this trait and the possibility of developing molecular markers to select superior genotypes.

***Resistance to wooly apple aphids -*** Woolly apple aphid, *Eriosoma lanigerum* (Hausmann) (Homoptera: Aphididae) has become a more severe pest in apple production areas in the past few years. The retirement of powerful organophosphate pesticides has also increased pressure on orchards. Orchards with resistant rootstocks have been shown to eliminate need for spraying for this pest because the insects cannot overwinter in the rhizosphere. Monogenic resistance to WAA derived from 'Robusta 5' has been mapped to chromosome 17 (Er2 locus) and has been utilized extensively in the Geneva, New York, and New Zealand breeding programs (Bus et al., 2008). Another resistance locus (Er3) from Aotea rootstock has also been mapped on chromosome 8, although it is not as effective as Er1 and Er2 (Sandanayaka et al., 2003; Sandanayaka et al., 2005; Sandanayaka and Backus, 2008). Phenotypic evaluation of this trait consists of rearing insects on susceptible germplasm and then transferring a specific number of insects on actively growing shoots of seedlings or replicated clones in a confined space (usually a netted greenhouse), then observing feeding and proliferation of WAA during a 2 month period after transfer (Beers et al., 2006). The monogenic nature of this type of resistance makes it amenable to utilization of cis-haplotype- specific markers to select parents and cull progeny that do not possess the resistance locus (Bassett et al., 2015). Other sources of WAA resistance are known in the Malus germplasm but very little is known about the genetic inheritance of these sources.

***Rootstock tolerance to phytoplasma and viruses -*** Apple viruses and phytoplasmas can cause losses in productivity by interdicting basic plant functions, deforming branches and roots, and by making fruit unmarketable. To date, these pathogens are known to be spread by grafting, where infected clonal rootstocks or scions are the media for transmission (Wood, 1996; James et al., 1997; Silva et al., 2008).

While the goal of apple industries throughout the world should be to work only with material that has been certified tested for viruses, phytoplasmas and other graft-transmissible agents, the eradication of these agents has been elusive due to propagation practices of some growers and homeowners that use infected sources of budwood. It is recommended that apple rootstock improvement programs pay some attention to phenotyping apple rootstocks for susceptibility to some or all of the possible graft-transmissible viruses or phytoplasmas (Lankes and Baab, 2011). Efforts have been made in Germany and Italy to produce rootstocks resistant to the proliferation phytoplasmas (*Candidatus Phytoplasma mali*) found in certain accessions of *M. sieboldii* (Seemuller et al., 2007; Seemuller et al., 2008) and *M. sargentii* (Bisognin et al., 2008, 2009; Jarausch et al., 2008; Bisognin et al., 2009). Susceptibility to Apple Stem Grooving Virus has been observed in 'Ottawa 3' rootstocks and some of its derivatives (G.16 and G.814) which exhibited stunting or death upon being grafted with an infected scion. The slow decline caused by graft union necrosis among certain rootstock/scion combinations in the presence of Tomato Ring Spot Virus (ToRSV) (Tuttle and Gotlieb, 1985a; Tuttle and Gotlieb, 1985,b) observed in MM.106 rootstock grafted with 'Delicious' scion is also of concern when breeding apple rootstocks. A large trial is underway in collaboration with Cornell University and Virginia Tech to evaluate 50 genotypes for this sensitivity (Robinson, personal communication). Furthermore, there is paucity of genetic studies that describe the inheritance of susceptibility of Malus germplasm to viruses and phytoplasmas, making genetically informed breeding impossible. In the Geneva breeding program, virus- sensitive parents like G.16 have been utilized for crosses, and efforts to map susceptibility loci are underway in collaboration with Cornell University virologists as a prerequisite to marker development to be utilized for culling susceptible seedlings before resources are wasted on growing them in larger field trials.

**<u>Coordinated testing and evaluation programs in the world</u>**

The varied environments where apples are grown suggest that no one rootstock will be well adapted to all environments and that coordinated, independent evaluation of new material from breeding program be performed by local pomologists. There are some organizations in certain apple growing regions in the world that aim to independently test rootstocks in a regimented way covering multiple environments and scions (Elfving and McKibbon, 1990; Schechter et al., 1991; Usa, 1991; Kviklys, 2011). A considerable program of tree fruit rootstock evaluation in the United States, Canada and Mexico is conducted by a group of 35+ researchers, extension specialists and industry collaborators within the CREES (cooperative research and extension services of the USDA) multi-regional project NC-140 (www.nc140.org) and in Europe through EUFRIN (www.eufrin.org). As a group the NC-140 researchers have made significant contributions to tree fruit rootstock research over the last 3 three decades and have conducted highly coordinated impactful research for the tree fruit industry (Rom and Rom, 1991; Fernandez et al., 1995; Perry, 1996; Autio et al., 1997, 2011a,b; Barritt et al., 1997; Marini et al., 2002; Marini et al., 2006b; Autio et al., 2011a; Autio et al., 2011b). Other organizations featuring coordinated international research on apple are RosBREED (www.rosbreed.org) (Iezzoni et al., 2010), FruitBreedomics (www.fruitbreedomics.com ) and, the Genome Database for the Rosaceae (www.rosaceae.org) are advancing the development of new knowledge about physiology, phenomics, genetics, and genomics of Rosaceaous crops and providing useful infrastructure to the development and evaluation of new apple rootstocks(Evans et al., 2012; Evans, 2013a; Evans, 2013,b; Peace et al., 2014; Chagne et al., 2015; Guan et al., 2015; Liverani et al., 2015; Mauroux et al., 2015; Fresnedo-Ramirez et al., 2016). The ultimate goal for all these organizations is to make apple growing more efficient, more environmentally friendly, more profitable for those that grow apples and more nutritious for the customers that eat apples, and the development of new apple rootstocks is an important cog in this intricate effort.

**Relationship to Other Projects Search -**

This research is closely tied to the evaluation and utilization of the apple germplasm collection 8060-21000-025-00-D, "Management of Apple, Cold-Hardy Grape, and Tart Cherry Genetic Resources and Associated Information" in Geneva NY with G.Y. Zhong and C.T. Chao as principal investigators – this project is the main source of novel breeding material for our program. CRIS PROJ NO: NYC-625410 "Identification and validation of novel genetic loci linked to fire blight resistance in apples" managed by Dr. Khan at Cornell University is closely associated to our research program in the development of resistance to fire blight in apple rootstocks. CRIS PROJ NO: CALW-2016-04616 “Characterizing genotype-specific apple root biochemistry and its implications for rhizosphere microbial ecology in apple replant disease (ARD)” is also closely associated with the program as we provide much of the germplasm and some of the root samples to investigate genotype specific associations with rhizhospheric biota. Dr. Fazio was one of the inceptors and Co-PI of NIFA SCRI CRIS PROJ NO: NYC-145543 “Accelerating the development, evaluation, and adoption of new apple rootstock technologies to improve apple growers’ profitability and sustainability” led by Dr. Cheng at Cornell University which aims to study many aspects of apple rootstock influence on fruit production that are multidisciplinary and related to the breeding program. The program also works closely with Dr. Zhu of the USDA ARS Tree Fruit Research Laboratory in PROJ NO: 2094-21220-002-10T “Phenotyping resistance traits of apple rootstock germplasm to replant pathogens” where germplasm from the breeding program is being used to discover QTLs and genes related to apple replant disease resistance. We collaborate with Dr. Mazzola also in Wenatchee in PROJ NO: 2094-21220-002-08T “Managing rhizosphere/soil microbiology via apple rootstock chemistry” to study aspects of soil biology related to apple rootstocks. We also collaborate with several scientists at the USDA Appalachian Tree Fruit Research Station in Kearneysville, WV, with PROJ NO: 8080-21000-023-00D “Genetic improvement of fruit crops through functional genomics and breeding” where we are investigating the effect of specific genes on tree architecture and PROJ NO: 8080-21000-024-34S “Three-dimensional modeling system for fruit trees” to see how rootstocks influence the architecture of apple trees. PROJ NO: 8080-21000-024-00D “Integrated orchard management and automation for deciduous tree fruit crops” with Dr. Tabb to investigate how apple rootstocks can aid in developing optimal canopies for orchard automation. The program also collaborates closely with ~35 scientists from all apple growing regions in North-America participating in the NC-140 multi state project CRIS PROJ NO: MO-MSPS0006 “Improving economic and environmental sustainability in tree-fruit production through changes in rootstock use”. PROJ NO: 8060-21000-026-02N “Development of apple rootstock technologies for U.S. and Brazilian apple growers” is one of the many international research projects aimed at studying apple rootstock performance. Our project is the result of a close collaboration between Cornell University and USDA ARS. This collaboration has been ratified with a Cooperative Research and Development Agreement (CRADA No. 58-3K95-4-1668-M)

**APPROACH AND RESEARCH PROCEDURES**

**Objective 1:** Develop and release improved apple rootstocks by leveraging advances in marker assisted breeding, including construction of genetic maps, establishing trait associations, gene discovery for important rootstock traits (dwarfing, early bearing, yield efficient, fire blight resistant), and screening for novel alleles for important rootstock traits.

**Sub-objective 1A** Perform all breeding and evaluation stages involved in the 15-30 year process of developing new rootstocks with the assistance of recently developed breeding tools, such as marker-assisted selection.

***Non Hypothesis Goal Driven 1A*** *Perform all breeding and evaluation stages involved in the 15-30 year process of developing new rootstocks with the assistance of recently developed breeding tools, such as high throughput phenotyping and marker-assisted breeding.*

***Experimental design 1A*****:** We will select new parents based on their genetic potential and field performance. We will generate new genotypes by crossing these parents and we will continue data collection and subsequent selection on approximately 4,000 genotypes that are at different evaluation and selection stages of the breeding pipeline. This includes performing multi-state and international advanced orchard trials, advanced cooperator trials with commercial stool-bed nurseries and first test orchards on location.

A Crossing Block composed of elite germplasm and commercial varieties is in place in Geneva, NY and will be used to generate new populations segregating for rootstock quality traits (propagation, dwarfing, and precocity) and disease resistance. We will follow the ten-stage selection and evaluation protocol outlined in Johnson (2001) with some modifications regarding the utilization of molecular markers to assist selection and the incorporation of newly identified traits. This process is also outlined in a flow chart diagram attached to this document describing the breeding program (Page 6). We currently have plants in all of these stages and expect to perform all operations within these stages during the next five year period. Due to space and resource constraints we begin a new breeding cycle (lasting 15-30 years) every three years. We expect to initiate two breeding cycles during the five year period of this project.

**Stage 1. Parental Selection, hybridization, disease screenings, stool plant establishment, Years 1-2 / 2,000-10,000 seedlings.** Parental combinations that have complementary characteristics are chosen for hybridization; for example, an easily propagated dwarfing parent might be crossed with a disease resistant parent. Seeds are collected from the fruit of these crosses, and the seed are stratified (cold treated to break dormancy) and germinated. We then inoculate the seedlings with fire blight bacteria *(Erwinia amylovora)* (Gardner *et al.* 1980) and crown rot fungus (*Phythophthora* spp.) (Cummins and Aldwinckle 1974). Based on the results of previous selection cycles we expect to eliminate 50-80% of the seedlings and establish the rest as single plant stool tree populations. DNA is extracted from all surviving seedlings and tested for dwarfing loci and other markers associated with important traits using high throughput PCR markers (SCARs) that have been developed in our laboratory (Appendix B Figure 4). Depending on the parents used, markers generally eliminate 75-95% of surviving seedlings. *Contingency:* If parents selected for breeding do not have the necessary horticultural and resistance traits then we will select from a pool of novel accessions. If a new virulent pathovar overcomes known resistance then we will search the accessions for resistance to the new pathovar. If PCR markers don't perform as expected for selection, then we will search for alternative methods of high throughput screening.

**Stage 2. Stool plant selection, nursery liner establishment, nursery tree growth, Years 3-4 / 25-100 stool trees.** Genotypes are propagated as single tree stool-bed plants which are then used to propagate rootstock liners harvested from genotypes that show adequate rooting (at least three adventitious roots per shank) and do not have brittle wood. Liners are moved to a nursery (McCarthy farm, Cornell University – Geneva, NY) for years 5 and 6, where finished trees are produced (it takes at least 2 years to make a finished tree: harvest rootstock liner from mother plant in Fall of year 1; plant in field nursery in Spring of year 2; graft scion bud in Summer of year 2; cut tops of rootstock liners in Spring of year 3 to allow grafted bud to push; allow grafted bud to grow a full finished tree in Summer of year 3; harvest finished tree in Fall of year 3; plant finished tree in the field experiment in Spring of year 4 – the procedure can be cut one year if bench-grafts are used instead of August budding). In years 5 and 6 stool trees are again evaluated for resistance to fire blight and for infestation levels with woolly apple aphids (Johnson 2000), and susceptible genotypes are discarded from the nursery and from the stool tree fields. *Contingency*: If stool bed tests for rooting don't work on a particular year then we will repeat them on a subsequent year. If field fire blight and wooly apple aphid tests are inconclusive we will repeat them in a more controlled environment (greenhouse) in successive years.

**Stage 3. First test orchard establishment, precocity evaluation and selection, Years 5-6 / 25-50 rootstock genotypes.** Because marker assisted selection for dwarfing has been implemented, we expect the vast majority of rootstocks to be dwarfing and we will plant four to six finished trees on each rootstock genotype in a medium density first test orchard in two locations in the U.S. In addition to the test genotypes, size standard varieties are included (M.27, M.9, M.26, MM.106). Trees are trained to develop an open branching pattern, but pruning is allowed to pattern a slender spindle system. Data is collected and analyzed annually for yield, yield efficiency, tree vigor, suckering, nutrient uptake efficiency and response to any unique stress events. *Contingency*: If dwarfing phenotype is not recovered efficiently by markers then we will cull larger trees in the orchard.

**Stage 4. First test orchard evaluation and selection, elite stool bed establishment, Years 7-12 / 10-15 rootstock genotypes.** Rootstock genotypes that exhibit precocity and adequate yield efficiency by the fourth leaf (year 10 of breeding cycle) are propagated to increase plant material for an elite stool bed in two locations (Geneva, NY and at cooperating nurseries in the North West). Stool beds are developed from liners retained from stage 2 or from root cuttings of older orchard trees. *Contingency*: If we are not able to identify precocious genotypes in the test orchard then we will test individuals from different crosses and populations. If we are not able to propagate the selections using root cuttings we will consider the utilization of other methods to establish new elite stool beds.

**Stage 5. Liner production, stool bed evaluation, nursery tree growth, Years 10-15 / 5-10 rootstock genotypes.** The important characteristic of this stage is that by this time we have enough stool bed material (liners) to be able to run replicated tests and produce a reliable estimate of how resistant or tolerant a selection is to the different biotic and abiotic stresses that the genotypes will be faced within the life of an orchard. This critical number of plants per genotype is between 100-1000 and is very difficult to achieve with conventional propagation methods and may be best achieved through micropropagation (Fazio et al. 2015b). At this stage we produce trees with several scion/rootstock combinations to test graft union compatibility and strength. Liners in the nursery are budded with selected scions to produce 30 high quality finished trees. First test orchards are removed after harvest in year 15 (after 9th leaf). After 30 trees are produced in the nursery, liners are collected from elite stool beds and subjected to evaluations of disease resistance and stress tolerance, extreme temperature soil tests (trees are grown in heated pots), replant soil tests (Isutsa and Merwin 2000), fire blight tests, crown rot tests, virus resistance / hypersensitivity tests, graft union strength tests (3-4 year old finished trees with several scion/rootstock combinations are subjected to mechanical stress at the graft union) while in stages 5-7 (Fazio, 2015). Protocols and methods for these techniques are published (J. Cummins and H. Aldwinckle 1974). *Contingency*: In the event that the stress tolerance tests are not adequate then we will investigate novel ways to test for cold tolerance, soil heat tolerance, etc. If second battery of disease resistance screens reveals susceptible individuals then we will investigate to correct initial screens.

**Stage 6. Intermediate stage orchard establishment and early evaluation, Years 16-18 / 10 rootstock genotypes.** Intermediate stage orchards are planted beginning in year 16 at three sites representing a cross-section of domestic apple production environments. Each year's planting includes commercial standard dwarfing genotypes (M.9, B.9, M.26) and 5 to 10 elite rootstock genotypes that have shown promise in elite stool bed liner production, initial test orchard performance, and biotic and abiotic stress resistance screens. These orchard trees are evaluated for precocity in their early years.

**Stage 7. Intermediate stage orchard evaluation, commercial stool bed trials, Years 19-21 / 5 rootstock genotypes.** Intermediate stage orchard trial data collection continues (Russo et al., 2007). Biotic and abiotic stress screenings of rootstock liner trees is completed. The most promising rootstock genotypes (a maximum of 5 per year) from the Cornell/USDA program are distributed to cooperating nurseries for commercial stool bed trials (50 liners to each of 2 cooperating rootstock nurseries) beginning in year 19. The most promising Geneva rootstock genotypes are submitted for phytosanitary certification (NRSP5, Prosser WA) to enable international distribution. It is possible to start the technology transfer to cooperating nurseries at stage 5 or 6 because these nurseries may be the location where the finished trees for intermediate trials are prepared. In that contingency we will transfer plant material (rootstock liners) to cooperating nurseries under contract to generate finished trees. Data on nursery tree performance will be collected at this stage (Fazio et al., 2008a). This will also allow cooperating nurseries to take a first look at these selections and learn to the best cultural practices adapted to the new genotypes.

**Stage 8. NC-140 and on-farm trials, distribution to all cooperators, Years 22-24 / 2 rootstock genotypes.** Intermediate stage orchard trial data collection continues (Robinson et al., 2006). For outstanding rootstock genotypes from the intermediate stage orchard trials and commercial nursery stool bed trials, liner production from cooperating nurseries is used to propagate trees for NC-140 and/or on-farm trials. Each multi-state NC-140 trial and on-farm grower cooperator trial is unique and follows methods and protocols that are established by the cooperators participating in the trial. Generally, data on yield efficiency, productivity, precociousness, hardiness, incidence of disease, tree size is collected for each rootstock for a period of 8-12 years. Best rootstock genotypes, as determined by each unique individual trial's protocol, are distributed to domestic cooperating nurseries for propagation, and to international cooperating nurseries and institutions for propagation and local evaluation trials. Internationally commercially successful genotypes join the USDA/Cornell rootstock evaluation program as stage 8 materials following evaluation in biotic and abiotic stress screenings – this is done to provide a benchmark for all commercial rootstocks.

**<u>Stage 9. Final evaluations and selections, commercial ramp-up, patent applications, Years 25-27 / <1 rootstock genotype.</u>** Plant material for rootstock genotypes demonstrating marked improvement over commercially available varieties based on results from cooperator and NC-140 trials is increased in commercial stool beds and micropropagation facilities. Intermediate stage evaluation orchards are removed after 11th leaf. Plant Patent and UPOV protection applications are filed on commercially viable rootstock genotypes given that the IP protection is necessary for successful deployment and implementation of the new genotypes.

**<u>Stage 10. First commercial sale of Geneva rootstocks, elimination of all unreleased genotypes from trials, Years 28-30.</u>** Data collection continues for NC-140 and on-farm grower cooperator trials. Unreleased genotypes that showed promise but were not demonstrably superior to commercially available rootstocks are eliminated from the program or selected for release in alternative markets (ornamental etc.).

***Contingencies*****:** There are several contingency points in this part of the project as there are many stages. Amendments to the breeding protocol will be made to include innovations in propagation, molecular markers.

***Collaborations*****:** *Domestic collaborators:* Awais Khan, Cornell University, collaborates on fire blight resistance characterization and inoculation, phytopthora root rot inoculations, tissue culture and genetic engineering. T. L. Robinson, Cornell University, provides second test and intermediate orchard evaluation, national and international evaluation of Geneva rootstocks, and commercialization. John Norelli (fire blight resistance), Chris Dardick (modification of plant architecture by rootstocks), all from ARS Kearneysville, West Virginia; C.T. Chao (novel gene pools for rootstock traits) ARS, Geneva, New York; Mark Mazzola and Yanmin Zhu (replant tolerant rootstock genotypes) ARS Wenatchee, Washington. Willow Drive Nursery provides advanced testing locations for stool bed evaluation, nursery tree development and is one of our stakeholders. Dr. Stefano Musacchi (Wenatchee, WA) is testing advanced selections in Washington State. The Washington Tree Fruit Research Commission performs advanced apple rootstock testing including intermediate and commercial trials in organic and replant situations. The NC-140 network of collaborators (list available at www.nc140.org ) is essential for proper testing of local adaptations of these new genotypes.

*International collaborators*: A network of international test sites in which we are actively involved was established in the past 10 years. These test sites are in Germany, France, Italy, Poland, New Zealand, Australia, South Africa, South Korea, Brazil, Uruguay, and Chile and include representatives from major research institutions (University of Bologna, Italy, IRTA, INRA, EMBRAPA) and representatives from international nursery organizations.

**Sub-objective 1B** Identify and characterize novel germplasm, genes, alleles and trait loci through quantitative trait analyses leveraging new genetic-physical maps.

***Hypothesis 1B*** *Novel genotyping and phenotyping techniques will allow the discovery of novel sources of germplasm and alleles to be used as new parents in the breeding program.*

**Experimental Design 1B.** The program has utilized Single Nucleotide Polymorphism (SNPs), Insertion-Deletion (InDel), microsatellite or simple sequence repeats (SSR) markers to generate DNA fingerprints of apple rootstock populations and potential parents. While these genotyping methods have positive aspects, they mostly lack information about functionality (direct connection to genes) and are not set up to generate haplotype data based on combinations of polymorphisms in longer stretches of DNA. Because of advances in sequencing technologies, in the next five years the program will transition to genotyping by AmpSeq (Yang et al., 2016) which allows the multiplexed (380 individuals x 300 amplicons – Cadle Davison pers. comm.) genotyping of stretches of DNA amplified by PCR. Amplicons are targeted to genes or specific regions of the genome and the assembly of the sequences onto the apple genome (Velasco et al. 2010; Fazio et al., internal resource), differentiating and grouping sequences based on similarity and haplogroups. Segregation will allow the distinction between homologous and homeologous genes (*Malus* is an ancient tetraploid). We will target a set of genes whose expression is segregating in rootstock breeding populations that have been characterized by gene expression QTL (eQTLs) of published microarray experiments (Jensen et al., 2011; Jensen et al., 2012, Jensen et al., 2014) and eQTLs (internal data, unpublished) derived from RNAseq analyses of areal and root tissues of apple rootstock breeding populations. We will choose germplasm that possesses the best combinatorial arrangement of desirable loci from within the breeding program and novel germplasm from the Malus collection based on feedback from past and future phenotyping experiments (Fazio et al. 2014a; Bassett et al., 2011). As clonally propagated material becomes available, we will design a series of replicated pot experiments (based on statistical power analysis for key parameters) where we will treat rootstocks and finished trees with different water regimens and aeroponically delivered pH treatments. Means and effects will be calculated and relevant multivariate analyses will be conducted for measured parameters including tree growth, photosynthesis, nutrient concentration in the leaves or fruit, tree architecture parameters (bud break, rooting, root morphology, branching, growth, flower induction). We are currently running phenotyping experiments involving root growth imaging and sensing with CI-600 root imagers and root analysis software (CID Bio-Science, RootSnap, Giaroots, etc.) and pH-nutrient treatments in connected aeroponic systems (Appendix B Figures 1-3). We see potential for these measurements to help us and apple growers make more informed decisions regarding the type of rootstock that matches their pedo-climatic conditions. Once the methodology is standardized and the results are interpreted it will be incorporated into the breeding process, possibly at stage 5-8 where availability of enough clonal replicates (rootstock liners) is assured. We will seek collaborations with expert physiologists, plant pathologists, etc. to help in the design and interpretation of these experiments.

***Contingencies*** If AmpSeq is difficult to implement, we will seek similar, high throughput genotyping systems as they become available or continue using Malus Consortium Illumina SNP Chips. Expert labor, cost, instrument, greenhouse, plant and land availability are all limiting factors to the success of these experiments. We will tailor each experiment based on resources available each year.
***Collaborations*** Dr. Cadle-Davidson (USDA ARS, Geneva) on AmpSeq matters. Dr. Terence Robinson program (Cornell University) and other visiting scientists in his laboratory on evaluation of advanced breeding lines in different orchard systems. Drs. Dardick and Tabb (USDA ARS , Kearneysville, WV) in matters related to tree and root architecture and imaging. Dr. Michael Grusak (USDA ARS, Fargo, ND) in matters regarding nutrient content, impact on tree health and possibly human nutrition. Dr. Moran (University of Maine) to investigate low temperature stress on apple rootstocks. Plant pathologists at Cornell University and Dr. Mark Mazzola (USDA ARS, Wenatchee, WA) to devise and interpret experiments involving soil pathogens associated with replant disease, and Dr. Lee Kalcits (Plant Physiologist, Washington State) on matters of nutrient partitioning by apple rootstocks.

**Objective 2:** Identify and dissect important rootstock traits that modify gene activity in the scion, toward enhancing drought tolerance, tree architecture, propagation by nurseries, root growth and physiology, nutrient use efficiency, and disease resistance; incorporate this knowledge into breeding and selection protocols.
**Sub-objective 2A** Identify components of rootstock induced traits that modify gene expression and metabolic/physiological profiles of grafted scions to increase tolerance to abiotic stresses such as tolerance to drought, improve fruit quality and storability, increase tree productivity, disease resistance and nutrient use efficiency.

***Hypothesis 2A*** *Genetic maps, QTL analyses, RNAseq, gene expression QTLs, whole genome sequences can be used to deconstruct traits to their segregating components.*

**Experimental Design 2A** The Geneva breeding program has successfully used genetic maps in combination with phenotypic data to identify Quantitative Trait Loci (QTLs) associated with several important traits in apple rootstocks leveraging very diverse interspecific crosses. We know from Jensen et al., 2011 and 2012, that gene expression in the scion is modified by apple rootstocks, what we do not know is how genetically complex these scion expression modulations are in segregating rootstocks. Similarly to what has been done within our program with eQTLs, we will plant 1-2 apple rootstock replicated segregating populations, graft them with the same scion (Honeycrisp for example) and measure gene expression by 3' RNAseq (www.lexogen.com) , tree growth, photosynthesis, metabolites, nutrient concentration in the leaves or fruit, tree architecture parameters (bud break, branching, growth, flower induction) on the scion to detect rootstock induced gene expression QTLs and possibly associate them with physical traits measured on the same trees. For example, we have now very strong evidence of rootstock mediated nutrient absorption and translocation (our group was the first in the world to publish on the genetics of such traits) as demonstrated by this dual clustering diagram of boron concentration in grafted Honeycrisp scion from a field experiment with four years of data and multiple. We would take contrasting rootstocks and progeny to see what genetic elements are fostering such differences. In this case we have G.935 that consistently confers higher levels of boron and B.9 that has lower levels consistently. We also have a segregating population that is derived from the cross between G.935 and B.9. Depending on resources (funds and scientific effort) we plan to hold maximum of two experiments per year. The next iteration is to apply abiotic stresses on the same populations (drought, pH, lack of nutrients) and follow with performing similar measurements. The next phase is to connect known gene networks (based on functional annotations – MapMan and KEGG analysis software) segregating in the rootstocks with gene networks modulated in the scion by segregating rootstocks using multivariate analyses such as Ward's dual clustering analyses on correlation coefficients, principal component analyses and gene neural network analyses. The program has acquired next generation sequences (Illumina platform) of several founding parents of the apple rootstock breeding program (G.41, M.27, O.3, R.5, M.9, Dolgo), a complete genome assembly of R.5 (obtained by combination 100X Sequel – Pacific Biosciences, BioNano and Phase Genomics data) and has developed an internal database of aligned haplotypes for small genomic regions of interest such as genes with drastically changed expression (expressed or not expressed) identified in the eQTL discovery process. All of the above processes are very data intensive. To accomplish these tasks we will use a combination of off the shelf genomic analysis software, like SAS JMP Pro, Geneious (www.biomatters.com), JoinMap/MapQTL (www.kyazma.com), CLC Genomics Workbench (www.clcbio.com), we will also utilize genomic and breeder's tool box resources available through the Genome Database for Rosaceae (www.rosaceae.org), and other bioinformatic tools specifically designed by collaborators.

***Contingencies*** If methodology described above is not cost effective or fails to produce high quality data, we will seek different methods to genotype and phenotype plants in the populations. We will also continue to explore and adopt the best available, cost effective methodology to harness DNA information for breeding improved apple rootstocks. Current bioinformatic and statistical tools may not be well suited for our dataset types – we will seek advice from the NEA Compuational Biologist and/or Statisticians and, when necessary, devise new tools to enable the analysis and correct interpretation of the results.
***Collaborations*** We will collaborate with Dr. Udall and his team (Brigham Young University) with regards to the R.5 genome assembly to be used in this study. Dr. Dardick (USDA ARS, Kearneysville) will aid with mapping and statistical analyses.

**Sub-objective 2B** Validate relationships between trait components and overall apple tree performance in different rootstock-scion combinations and incorporate new knowledge into breeding and selection protocols.

**Hypothesis 2B** *Scion gene expression and phenotype modulation by segregating rootstocks transfers to other apple scions.*

**Experimental Design 2B** Based on the results of experiments in sub-objective 2A, we will validate the strongest rootstock induced scion trait associations on other apple scion varieties like Gala, Golden Delicious, SnapDragon, Autumn Crisp. As an example, if Gene A segregating in rootstock population R had an effect of increasing or decreasing phenotype Y (including gene expression) in Honeycrisp, does it have the same effect on SnapDragon scion? An experiment to validate such effect would only require a subset of rootstock germplasm segregating for such locus (15 with and 15 without) to test the mean separation between phenotypes of the groups (Jensen et al. 2015). We just started experiments in containers and in aeroponics deal with pH: three different levels (5.5, 7 and 8) to measure growth, nutrient uptake and root gene expression of grafted trees. Exploratory experiments with aeroponics: drought response where nutrient mist can be turned off for a number of hours (TBD) or drastically reduced. Items to be measured: physiological traits (photosynthesis, transpiration and hormonal activity), root and scion gene expression. Validated rootstock loci will be transitioned to working DNA markers and published.

***Contingencies*** In the event that we are not able validate effects of selected rootstock loci on phenotypes (including gene expression) of other scion varieties, we will select a new set of loci to validate.
***Collaborations*** We can perform this type of analysis in house, but will seek expertise and collaborations as needed.

**Physical and Human Resources**

The program enjoys cooperation with Cornell University under a Cooperative Research and Development Agreement (CRADA) 58-3K95-4-1668-M specifically with the Cornell University New York State Agricultural Experiment Station in Geneva (NYSAES). Approximately 25 acres of land belonging to NYSAES are dedicated to the apple rootstock breeding program, including land set aside for stool beds, stool nursery, tree nursery, first test orchards, and replicated trials. NYSAES provides rented greenhouse space for controlled experiments (inoculation, propagation), an aeroponic system able to accommodate 350 plantlets and 2000 sq. ft. cold storage space for storage and processing of finished trees and liners during winter months. The Field Research Unit of NYSAES provides (at a subsidized cost to the USDA) equipment and personnel necessary to conduct large field operations such as pruning, pesticide and herbicide spraying of orchards, etc. A Kubota and a John Deere tractors owned by the program are used for small field operations. Our laboratory is located in the Horticulture Section of the Cornell University Campus of NYSAES. It possesses modern molecular genetic laboratory equipment (water baths, freezers, pipetters, centrifuges etc.). This lab is equipped with a sequencing apparatus ABI3130 genetic analyzer for determining SSR parental allele sizes and a capillary sequencer to perform genotyping and DNA fragment sequencing. Seven 96 well thermal cyclers with high throughput agarose gel apparatuses (96-192 samples) are available to genotype with markers having allele size polymorphisms greater than 10bp. A ROCHE real time PCR machine capable of High Resolution Melting is also available to the lab. The program also has access to the Cornell Institute of Biotechnology Resource Center for services like Next Generation Sequencing, Microarrays, etc. Computer resources include a dedicated Dell and HP computers that are able to work with bioinformatics software like CLC Genomics workbench (www.quiagen.com) and Geneious (www.biomatters.com). Stable human resources for this project are Lead Scientist Geneticist Gennaro Fazio, Research Leader and Geneticist Gan-Yuan Zhong (5%), Field/Lab technician Todd Holleran, Lab Technician Sarah Bauer, and temporary labor pool during the summer months.

**Project Management and Evaluation**

This project is the result of collaboration between USDA ARS and Cornell University that is ratified with a CRADA. While the USDA has a lead role in the project, project co-directors (Dr. Robinson or his staff and Dr. Khan or his staff) meet regularly to evaluate progress, make critical management decisions about testing and release of apple rootstocks. We hold annual meetings and semi-annual phone conferences with Nursery and Industry cooperators to evaluate the progress of the breeding program. We hold regular (bi-weekly) staff meetings to plan and discuss progress on the project's milestones and regular meetings with collaborators in PGRU to coordinate efforts on germplasm collection and evaluation. We utilize tools like AT&T Connect to routinely share data, presentations and interact with collaborative scientists worldwide. Our ARS Location (Geneva) holds regular monthly meetings that include the Research Leader and all location scientists to coordinate research projects and discuss advancements in research.

We also routinely communicate with Area Director and members of the Office of National Programs staff regarding general direction of project, interaction with industry and progress with milestones.

**Data Management**

This project produces several types of data assembled in different sizes from small to very large. The smaller sets are phenotypic evaluations of several traits collected during the process of evaluation of genotypes in the breeding program – these sets also include the statistical analyses associated with the traits. Larger data sets are generated as a result of next generation sequencing of samples in the breeding program. All data is backed up and stored on an ARS secure server. Because we work under a CRADA (Cooperative Research and

Development Agreement) with Cornell University, the datasets germane to breeding program genotypes can only be released to the public upon agreement of both parties. This release has been accomplished in many cases through consensual publication. Sequencing datasets are usually published and deposited in related databases like www.rosaceae.org or NCBI when they are processed for publication.

**Milestones**

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|---|---|---|---|
| **Project Title** | **Development of Biotic and Abiotic Stress Tolerance in Apple Rootstocks** | **Project No.** | 8060-21000-026-00D |
| **National Program** | 301, Plant Genetic Resources, Genomics and Genetic Improvement | | |
| **Objective** | 1. Develop and release improved apple rootstocks by leveraging advances in marker assisted breeding, including construction of genetic maps, establishing trait associations, gene discovery for important rootstock traits (dwarfing, early bearing, yield efficient, fire blight resistant), and screening for novel alleles for important rootstock traits. | | |
| **Subobjective** | 1A. Perform all breeding and evaluation stages involved in the 15-30 year process of developing new rootstocks with the assistance of recently developed breeding tools, such as marker-assisted selection. | | |
| **NP Action Plan Component** | 1– Crop Genetic Improvement | | |
| **NP Action Plan Problem Statement** | Problem Statement 1B: New crops, new varieties, and enhanced germplasm with superior traits | | |

| Hypothesis | SY Team | Months | Milestones | Progress/ Changes | Products |
|---|---|---|---|---|---|
| Perform all breeding and evaluation stages involved in the 15-30 year process of developing new rootstocks with the assistance of recently developed breeding tools, such as high throughput phenotyping and marker-assisted breeding. | Fazio | **12** | Nearly all the procedures in this objective are cyclic in nature – almost every year we select parents, make crosses, select genotypes from first test orchards, inoculate seedlings, send test selections to cooperators, plant nursery, plant orchards, collect yield data, conduct Marker Assisted Breeding for dwarfing, WAA resistance, etc. | | Seed from crosses, selections, trees for testing on cooperators farms. Selections distributed to nurseries for advanced testing. Selections distributed to cooperators for comparative testing in multiple U.S. environments prior to release. |
| | Fazio | **24** | Select and establish 5 new female parent trees in crossing block | | |
| | Fazio | **36** | Implement new selection protocols for nutrition and root architecture | | Rootstock Release – this will be a rootstock that has probably been in the pipeline for 20 years. |
| | Fazio | **48** | Select and establish 5 new female parent trees in crossing block | | |

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| | Fazio | **60** | Implement new protocols for replant disease selection. | | Rootstock Release – this will be a rootstock that has probably been in the pipeline for 20 years. |

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| **Project Title** | **Development of Biotic and Abiotic Stress Tolerance in Apple Rootstocks** | **Project No.** | 8060-21000-026-00D |
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| **Subobjective** | 1B. Identify and characterize novel germplasm, genes, alleles and trait loci through quantitative trait analyses leveraging new genetic-physical maps. | | |
| **NP Action Plan Component** | 1– Crop Genetic Improvement | | |
| **NP Action Plan Problem Statement** | Problem Statement 1A: Trait discovery, analysis, and superior breeding methods | | |

| **Hypothesis** | **SY Team** | **Months** | **Milestones** | **Progress/ Changes** | **Products** |
|---|---|---|---|---|---|
| Novel genotyping and phenotyping techniques will allow the discovery novel sources of germplasm and alleles to be used as new parents in the breeding program. | Fazio | **12** | Identification of target genes (1500) and generation of PCR primers in preparation for AmpSeq. Amplicon optimization and validation. | | New set of apple primers for multiplexed AmpSeq – deposit to Rosaceae database. |
| | Fazio | **24** | Identification of parents and populations for screening with AmpSeq. Run AmpSeq on selected individuals. Design phenotypic experiments on selected individuals (pH, water use efficiency, nutrient uptake, root morphology, etc.) | | |
| | Fazio | **36** | Analysis of AmpSeq data, identification of unique alleles and haplotypes. Connection to legacy genotypic and phenotypic datasets. | | Candidate loci for incorporation into breeding program. If needed, transition to gel based PCR marker types. |

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| | Fazio | **48** | Selection and crossing of new individuals based on AmpSeq. | | Unique parents with desirable combinations of desired trait loci. |
| | Fazio | **60** | Second set of phenotypic experiments – to be determined upon need. | | |

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| **Project Title** | **Development of Biotic and Abiotic Stress Tolerance in Apple Rootstocks** | **Project No.** | 8060-21000-026-00D |
| **National Program** | 301, Plant Genetic Resources, Genomics and Genetic Improvement | | |
| **Objective** | 2. Identify and dissect important rootstock traits that modify gene activity in the scion, toward enhancing drought tolerance, tree architecture, propagation by nurseries, root growth and physiology, nutrient use efficiency, and disease resistance; incorporate this knowledge into breeding and selection protocols. | | |
| **Subobjective** | 2A Identify components of rootstock induced traits that modify gene expression and metabolic/physiological profiles of grafted scions to increase tolerance to abiotic stresses such as tolerance, improve fruit quality and storability, increase tree productivity, disease resistance and nutrient use efficiency. | | |
| **NP Action Plan Component** | Component 3 – Crop Biological and Molecular Processes | | |
| **NP Action Plan Problem Statement** | Problem Statement 3A: Fundamental knowledge of plant biological and molecular processes. | | |

| Hypothesis | SY Team | Months | Milestones | Progress/ Changes | Products |
|---|---|---|---|---|---|
| Genetic maps, QTL analyses, RNAseq, gene expression QTLs, whole genome sequences can be used to deconstruct traits to their segregating components. | Fazio | **12** | Selection of segregating populations and generation of clonally replicated materials for experiments. | | |
| | Fazio | **24** | Grafting of same scion, planting in pots or aeroponic systems. | | |
| | Fazio | **36** | Growth, phenotype measurements and sampling of RNA for 3'RNAseq. Subjection of experimental units to mild drought stress. | | Database of rootstock induced phenotype modulation (including gene expression) in non-stressed vs. stressed plants. |
| | Fazio | **48** | Analysis of first year data, collection of second year data. | | First gene network analysis and first set of candidate loci to test in sub-objective 2B |

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| | Fazio | **60** | Analysis of second year of data | | Publication of research findings |

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|---|---|---|---|
| **Project Title** | **Development of Biotic and Abiotic Stress Tolerance in Apple Rootstocks** | **Project No.** | 8060-21000-026-00D |
| **National Program** | 301, Plant Genetic Resources, Genomics and Genetic Improvement | | |
| **Objective** | 2. Identify and dissect important rootstock traits that modify gene activity in the scion, toward enhancing drought tolerance, tree architecture, propagation by nurseries, root growth and physiology, nutrient use efficiency, and disease resistance; incorporate this knowledge into breeding and selection protocols. | | |
| **Subobjective** | 2B Validate relationships between trait components and overall apple tree performance in different rootstock-scion combinations and incorporate new knowledge into breeding and selection protocols. | | |
| **NP Action Plan Component** | 1– Crop Genetic Improvement | | |
| **NP Action Plan Problem Statement** | Problem Statement 1A: Trait discovery, analysis, and superior breeding methods | | |

| Hypothesis | SY Team | Months | Milestones | Progress/ Changes | Products |
|---|---|---|---|---|---|
| Scion gene expression and phenotype modulation by segregating rootstocks transfers to other apple scions. | Fazio | **12** | | | |
| | Fazio | **24** | | | |
| | Fazio | **36** | Preparation of comparative rootstock subsets (presence/absence of target locus) and grafting of different scions. | | |
| | Fazio | **48** | Growth and collection of first year data in stressed and non-stressed comparisons. | | First validation of locus effects. Validation of gene networks associated with target loci. Identification of new genes associated with target pathways. |
| | Fazio | **60** | Measurement of second year of data. Transition of validated loci into haplotype specific markers to be used in breeding. | | |

**Prior Research Accomplishments**
**Terminating Project Number:** 8060-21000-026-00D
**Title:** Development of Pest, Disease Resistance, and Stress Tolerance in Apple Rootstocks
**Project Period (beginning and ending dates- Month/Day/Year): March 28 2013-March 27 2018**
**SY Time – Investigators: Gennaro Fazio (100%) Gan-Yuan Zhong (5%)**
**FTE 1.85: Todd Holleran (100%) Sarah Bauer (85%)**

**Project Accomplishments and Impact:**
**Objective 1 Develop superior apple rootstocks, applying advances in marker-assisted breeding for important traits such as dwarfing, precocity, wooly apple aphid resistance, and tree architecture.**

**Technology Transfer -** The major impact of the project relates to the adoption by the U.S. industry of new varieties released in the last cycle where, production of Geneva rootstocks increased from less than 1 million rootstocks/year in 2013 to roughly 10 million rootstocks/year in 2017. This was accomplished by numerous on farm field trials that proved the worth of these new disease resistant and productive rootstocks to the U.S. industry. These technology transfer efforts in the project earned the "Excellence in Technology Transfer" award from the Federal Labs Consortium (competed against NASA, DOE, NIH, and other federal agencies) in April, 2015 and discoveries on apple rootstock dwarfing loci published by the project earned the Outstanding Fruit Research Paper Award by the Journal of the American Society for Horticultural Science in August 2015.

**Release of New Apple Rootstock G.814**. The project provided new solutions and opportunities to the apple industry by releasing this rootstock that addressed issues like replant disease and fruit quality and size. This clonally propagated apple rootstock G.814 is a dwarfing, productive, early bearing, highly yield efficient, resistant to fire blight. Although it is susceptible to wooly apple aphids and to Apple Stem Grooving Virus (ASGV), G.814 has shown tolerance to the replant disease complex. G.814 produces scions that when fully developed are about 40% the size of a standard seedling apple tree. G.814 has the potential to increase productivity of larger, high quality fruit in marginal replanted orchard land.

**Release of new apple rootstock G.213**. Some apple scions like Gala have a tough time blooming in low winter chill subtropical regions. Apple growers needed yield efficient, disease resistant apple rootstocks when growing apples in low chill environments or when current environments are affected by climate change. The project is releasing a new productive, disease resistant apple rootstock which improves bud break and productivity in low chill environments such as Southern U.S., California and Brazil. This rootstock was developed over a 35 year process where it survived a series of inoculations with apple rootstock pests and pathogens (fire blight, crown rot and wooly apple aphid) and was tested over 25 years with multiple grafted scion varieties in multiple environments increasing productivity and producing scions that when fully developed are about 30-40% the size of a standard seedling apple tree. When clonally propagated in the stool bed the mother plants produce rootstock liners that are 30 to 50 cm tall with few spines. This new rootstock seems to be the first in the world that possesses the characteristic of increasing bud break in low chill environments of scion cultivars like Gala, therefore it will increase production of high quality fruit in apple growing regions in the U.S. and worldwide that are affected by low winter chilling hours.

**Characterization of rootstock nutrient uptake**. Apple rootstocks can affect the nutritional status of Honeycrisp and Fuji apples. Mineral nutrient status (calcium, potassium, nitrogen, magnesium and phosphorous) affects the eating quality, health, storability and appearance of apples like Honeycrisp causing many apples to be discarded or apple trees to produce poorly. Recently published in a grower oriented journal (New York Fruit Quarterly) is a first of its kind description of how apple rootstocks affect the mineral nutrient and nitrogen concentration of Honeycrisp and Fuji fruit grafted on more than 40 rootstocks in replicated field trials in New York apple growing regions. As the availability and knowledge of diverse rootstocks increases, it will increase the potential to impact fruit productivity, quality and ultimately profitability of our apple orchards. The choice of the best rootstock for the site, scion and orchard system is going to become more important than ever. The ability to match the nutritional requirements of a scion cultivar to a specially tuned rootstock will enhance orchard management in the future by allowing healthier trees and more efficient use of fertilizers. This study, first of its kind, lays the foundation for this line of research and will provide better choices to our apple growers in terms of rootstock technologies.

The results of a decade long field trial of 48 apple rootstocks grafted with the apple variety Fuji were published. Rootstocks had significant influence on fruit yield and fruit nutrient concentration. Several Geneva® rootstocks evaluated showed considerable promise as alternatives to M.9. CG.6006, CG.8189, CG.4004, CG.5087, CG.4011, G.969, G.935, and G.890 had good performance on 'Fuji'. The rootstock induces changes in the concentrations of leaf and fruit nutrients. Cumulative yield efficiency had a moderate positive correlation with leaf Ca concentration. G.214, JM.10, CG.4003, M.9, G.935, CG.4088, CG.2406, G.969, and G.210 had low alternative bearing which means stable production of flowers and fruit year over year. All these data help apple growers determine the best rootstock for their local growing condition and variety and provide apple consumers with consistent high quality apples.

**Graft Union Strength of Geneva Apple Rootstocks.** In collaboration with Utah State University we published research on graft union flexural strength which won the 2016 U.P. Hedrick award of the Journal of the American Pomological Society. Apple rootstock 'Geneva® 41' ('G.41') and other rootstocks form weak graft unions with multiple scions, this is a problem in the nursery stage of tree development especially under high wind conditions which may cause losses upwards to 80% of trees in some rootstock/scion combinations – one grower reported the loss of 60,000 trees worth more than $600,000. Exogenous plant growth regulators (PGR) can influence vascular differentiation and wood formation, and thus may improve graft union strength. A series of commercial and experimental PGR formulations were applied to trees on 'G.41' rootstock over two seasons, and graft union strength and flexibility were measured. Benzyl adenine (BA) applied in paint solution to the graft union significantly increased the flexural strength per scion cross-sectional area and the flexibility of the union. In addition, foliar applications of Prohexadione-Ca also increased graft union flexural strength and flexibility, but temporarily limited scion extension growth. Applying PGRs in the nursery to more brittle rootstock-scion combinations may be an option for improving graft union strength and preventing tree losses. However, more efficient methods of application are needed for this approach to be commercially viable.

We are continuing work to further develop accomplishments in Objective 1: a. we will continue to release new apple rootstocks; b. we continue to work on nutrient uptake genetic and breeding; c. we continue to work on the analysis of micro-CAT scans of graft unions to establish morphometric parameters of comparison between strong and weak unions.

**Objective 2: Devise and apply genomic and bioinformatic tools for marker-assisted breeding of apple rootstocks including identification of the genes underlying resistance to the replant disease complex and to nutrient uptake efficiency.**

The bioinformatic portion of this objective was accomplished before the separation of Dr. Baldo (20%) from the project early during the course of this reporting period.

**Tool for identification of gene variants for rootstock breeding.** Once a genomic region is identified as being important for the modulation of a specific important trait it is difficult to identify other apple plants that may contain the trait associated genomic region. To solve this we have analyzed raw Genotyping-by-sequencing data from 1995 accessions of apples (31 species) from the Geneva apple germplasm repository and selected additional breeding material. The SNPs identified were made viewable on the published genome assembly, while diversity is also viewable in chromosome order in Tassel software. This makes it possible to identify SNPs among wild and breeding material near and in candidate genes of interest. This tool has the potential to speed up the breeding process, and identify new sources of important apple rootstock traits. (Baldo, Zhong)

**Validation of location and effect of dwarfing genes in the apple genome and relationship to early bearing induction in apple trees**. One trait that makes apple rootstocks very special in the realm of fruit production is the ability to dwarf trees and make them more productive earlier in the life of the orchard. It is estimated that the implementation of these traits in U.S. apple production has increased productivity by more than $0.75B in the past 30 years. Being able to track the origin and effect of these traits will enable the breeding and selection of new disease resistant improved apple rootstocks. In FY 2013 we completed a genetic map that utilized markers developed by the RosBREED consortium to examine the genetics of dwarfing and early bearing in two apple rootstocks breeding populations. The results of this genetic quest confirmed earlier findings by our lab and made possible modeling of dwarfing gene interactions. This accomplishment made quicker the development of new early bearing apple rootstocks and improved prediction of dwarfing potential of such apple rootstocks. (Fazio)

**We made a first report about the genetics of nutrient absorption by rootstocks in tree fruits.** We utilized quantitative trait analysis in a breeding population to uncover gene locations for leaf mineral concentrations of leaves for important plant nutrients like potassium (K), sodium (Na), phosphorous (P), calcium (Ca), zinc (Zn), magnesium (Mg) and molybdenum (Mo). We also noticed that several nutrient concentrations were correlated indicating the co-absorption or common transport mechanisms for some nutrients. We found significant positive linear correlations between Ca and Cu, Mg, P, and S. A significant correlation was also detected between Cu and K, Cu and P, also between K and P and between S and P. Segregation of a major gene for leaf K concentration in certain rootstocks had strong effects on the concentrations of other nutrients in the leaves, suggesting that it might be a good target for selection in the breeding program. As this is a first report, we are attempting to understand the physiological influence of these genes on other measurable traits in apple rootstocks and scions. It is possible that even subtle changes in plant nutrients caused by variable gene combinations in the rootstocks can affect productivity and disease resistance of apple trees. (Fazio)

**Genes activated during infection with components of replant disease.** RNA-seq technology was applied to identify the transcriptomic changes associated with apple root defense response to Pythium ultimum infection. Genes encoding homolog proteins with functions of pathogen detection such as chitin elicitor receptor kinase (CERK) and wall-associated receptor kinase (WAK) were among the differentially expressed apple genes. The biosynthesis and signaling of several plant hormones including ethylene, jasmonate and cytokinin were specifically induced in response to P. ultimum inoculation. Genes encoding enzymes of secondary metabolisms, cell wall fortification and pathogenesis related (PR) protein, laccase, mandelonitrile lyase and cyanogenic beta-glucosidase were consistently up-regulated in the later stages of infection.

We are continuing work to further develop accomplishments in Objective 2: we are using data generated in this objective to clone and identify genes and gene networks associated with root and rootstock traits which is related to Objective 2 of the new project plan.

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**Past Accomplishments of Investigators**

**GENNARO FAZIO**

**EDUCATION**

**Ph.D.** University of Wisconsin-Madison Department of Plant Breeding and Plant Genetics. Area of study: Application of molecular markers for breeding, quantitative genetics, plant variety identification. November 2001.

**M.S.** Agronomy-Molecular Biology, Brigham Young University, Provo, Utah, April 1997. Area of study: Identification of molecular markers linked to crown rot resistance in tomato.

**B.S.** Molecular Biology and Agronomy, Chemistry minor, BYU, Provo, Utah, 1995.

University of Bari, Italy, Agronomy Department, attended 1986-1987.

**PROFESSIONAL EXPERIENCE**

Research Geneticist, Plant Genetic Resources Unit, USDA-ARS, Geneva NY (2001-present).

Adjunct Professor, Dept. of Horticulture, Cornell University, Geneva NY (2001-present).

Research Assistant, University of Wisconsin-Madison (1997-2001).

**ACCOMPLISHMENTS**

1. Patented and released 13 apple rootstocks (G.41, G.935, G.202, G.210, G.214, G.890, G.969, G.814, G.213, G.778, G.228, G.189 and G.222) in the U.S. and internationally. These new rootstocks provide protection from fire blight, tolerance to replant disease, and increased productivity in the orchard. Production of these new Geneva® rootstocks in 2017 approached 10 million plants in the U.S. and is increasing.
2. Discovered inheritance of dwarfing, precocity, fire blight resistance, root morphology, scion branch angle modification in apple rootstocks.
3. Developed marker assisted breeding scheme for selection of dwarfing, precocious, disease resistant rootstocks.
4. Developed concept and initial experiments for the use of prohexadione (Apogee) in apple rootstock liner production. Several apple rootstock nurseries worldwide have adopted this method to increase quality and yield of propagation beds.
5. Discovered quantitative trait loci associated with nutrient absorption and translocation into the scion for important plant nutrients like potassium (K), sodium (Na), phosphorous (P), calcium (Ca), zinc (Zn), magnesium (Mg) and molybdenum (Mo). This study is the first one of its kind performed on apple rootstocks.
6. Characterized in a collaborative study the influence of apple rootstocks on the expression of scion genes.

**SELECTED HONORS**

Co-awardee of the 2016 U.P. Hedrick award of the Journal of the American Pomological Society.

Journal of the American Society for Horticultural Science Outstanding Fruit Research Paper Award for the year 2014, awarded August 2015.

Federal Laboratory Consortium for Technology Transfer "Excellence in Technology Transfer" award winner in 2015 for "New Productive, Disease Resistant Apple Trees".

North Atlantic Area Technology Transfer Award Winner in 2014 for development and commercialization of apple rootstocks critical for the U.S. industry.

**SELECTED RECENT INVITED PRESENTATIONS in reporting period 2014-2018:**

Utah State Horticulture Association Annual meetings Jan. 2017 Keynote "Overview of current rootstock technologies" and "Breeding methods for development of new apple rootstocks"

Kazakh National Agrarian University Dec. 2016 "Review current research on apple breeding" and "Apple rootstock technologies to aid Kazakh apple growers".

International Fruit Tree Association Annual meetings Feb. 2016 "Rootstocks Matched to Varieties".

Europa Fruit Tree Rootstock Consortium Aug. 2015 Angers, France. "Breeding and selection of Geneva® apple rootstocks"

University of Guelph, Department of Plant Agriculture Winter 2015 Seminar Series. "Leveraging genomic resources to breed a difficult perennial crop: apple rootstocks"

Ohio Produce Growers and Marketers (OPGMA) 2015 Congress. January, 2015, Sandusky, OH. "Updates from the National Apple Rootstock Breeding Program"

Washington State Horticulture Society Annual Meetings, Special Rhizosphere Symposium. Kennewick, WA. December 2014. "Optimal tree nutrition and fruit production begins underground – the apple rootstock story"

The Arsenal, Central Park, NYC Parks, New York, NY. October 2014. Title: "Importance of germplasm conservation in context with the loss of wild apple forests in Kazakhstan"

**SELECTED PUBLICATIONS in reporting period 2014-2018**

Fazio, G., 2017. Evaluating and improving rootstocks for apple cultivation. http://dx.doi.org/10.19103/AS.2016.0017.08 © Burleigh Dodds Science Publishing Limited, 2017.

Stuart Adams, Brent L. Black, Gennaro Fazio and Nicholas A. Roberts 2017. The Effect of Plant Growth Regulators on Apple Graft Union Flexural Strength and Flexibility. J Am Pom Soc. (APS) 71:8-18

Norelli JL, Wisniewski M, Fazio G, Burchard E, Gutierrez B, et al. (2017) Genotyping-by-sequencing markers facilitate the identification of quantitative trait loci controlling resistance to Penicillium expansum in Malus sieversii. PLOS ONE 12(3): e0172949. https://doi.org/10.1371/journal.pone.0172949

T. Tworkoski, G. Fazio and D.M. Glenn 2016. Apple rootstock resistance to drought. Scientia Horticulturae 204:70-78.

T. Tworkoski and G. Fazio 2016. Hormone and growth interactions of scions and size-controlling rootstocks of young apple trees. Plant Growth Regulation 78:105-119.

S. Shin, P. Zheng, G. Fazio, M. Mazzola, D. Main and Y. Zhu 2016. Transcriptome changes specifically associated with apple (Malus domestica) root defense response during Pythium ultimum infection. Physiological and Molecular Plant Pathology 94:16-26.

Z. Migicovsky, K.M. Gardner, D. Money, J. Sawler, J.S. Bloom, P. Moffett, C.T. Chao, H. Schwaninger, G. Fazio, G.-Y. Zhong and S. Myles 2016. Genome to Phenome Mapping in Apple Using Historical Data. The Plant Genome.

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**Gan-Yuan Zhong, Ph.D.**

Research Leader/Supervisory Plant Geneticist, USDA-ARS, Grape Genetics Research Unit, Plant Genetic Resources Unit

**Education:**

1991 Ph.D. Genetics, University of California, Davis.

1985 M.S. Crop Genetics and Breeding, Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences, Beijing, China

1982 B.S. Agronomy, Jiangsu Agricultural College, China

**Professional Experience and Research Accomplishments:**

**January 2010 – Present, Research Leader, USDA-ARS, Plant Genetic Resources Unit**

- Characterized fruit composition and content of polyphenolic compounds in the USDA-ARS *Vitis* germplasm
- Co-led an effort in genotyping USDA-ARS apple and grape collections and mapping populations using the SNP chips and genotyping-by-sequencing techniques.
- Contributed to various USDA-ARS NPGS missions and activities, particularly those relevant to the USDA-ARS Geneva genetic resources.

**May 2007 - Present, Research Leader, USDA-ARS, Grape Genetics Research Unit**

- Demonstrated genome-scale mRNA transmission between scions and rootstocks in grapevine
- Determined the likely genetic and molecular basis for several fruit quality traits of grapes
- Investigated genetic factors controlling resistance to root-knot nematodes and evaluated the feasibility of developing a transgenic solution to root-knot nematodes in grapevines
- Investigated the genetic and molecular mechanisms controlling grapevine plant architecture

**2004 - 2007, Senior Research Scientist, Pioneer Hi-Bred International, Inc. A DuPont Business**

- Developed and implemented molecular markers and other molecular breeding technologies in maize research and product development
- Conducted genetic dissection of complex traits in maize
- Developed and implemented molecular characterization tools for maize transgenic trait and technology development

**1995 – 2004, Research Manager/Scientist, Pioneer Hi-Bred International, Inc.**

- Led a Transgene Genetics Project for research on transgene silencing and position effect of transgenes in maize
- Carried out QTL mapping of seed quality traits in maize
- Managed product development process, regulatory compliance, and field operations for transgenic maize product development

**Recent publications**

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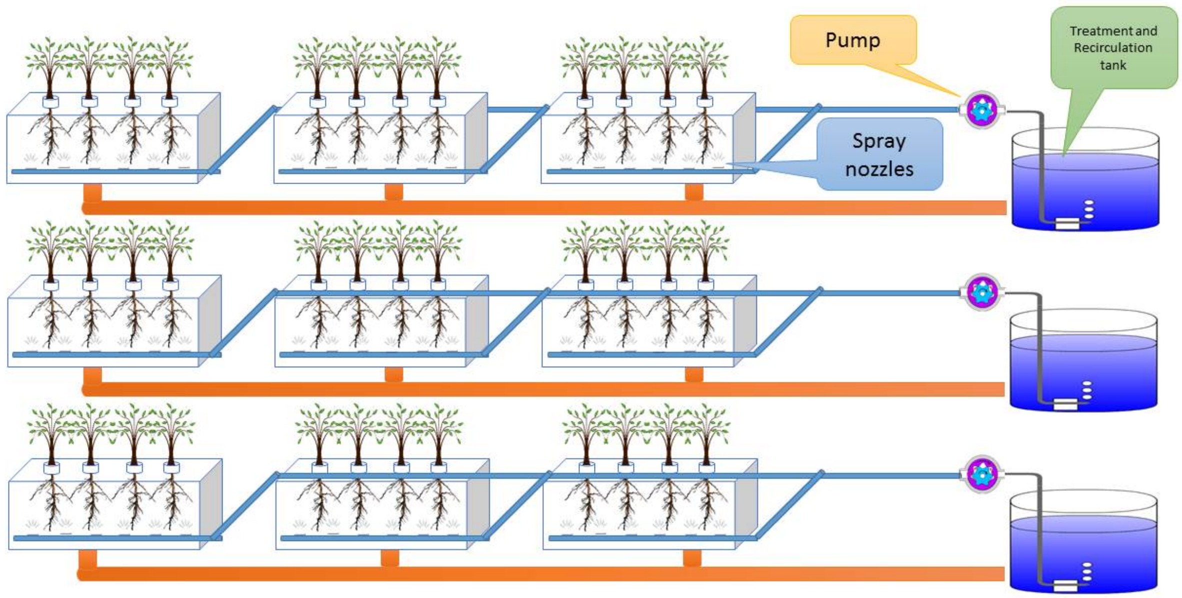
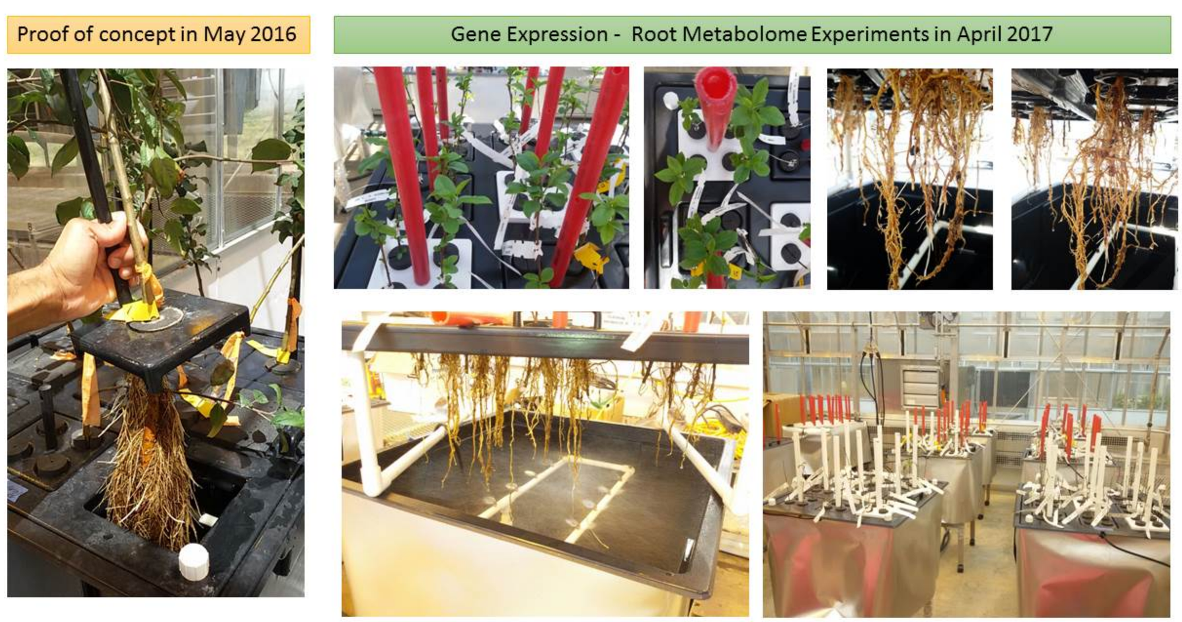
Appendix B – Additional Figures.




Appendix Figure 1. Schematics of aeroponics system built in Geneva NY in 2017. We plan to expand capabilities of these systems or build new ones with additional sensors.




Appendix Figure 2. Ability to study root systems without the encumbrance of soil is one of the advantages of growing apple roots in air.

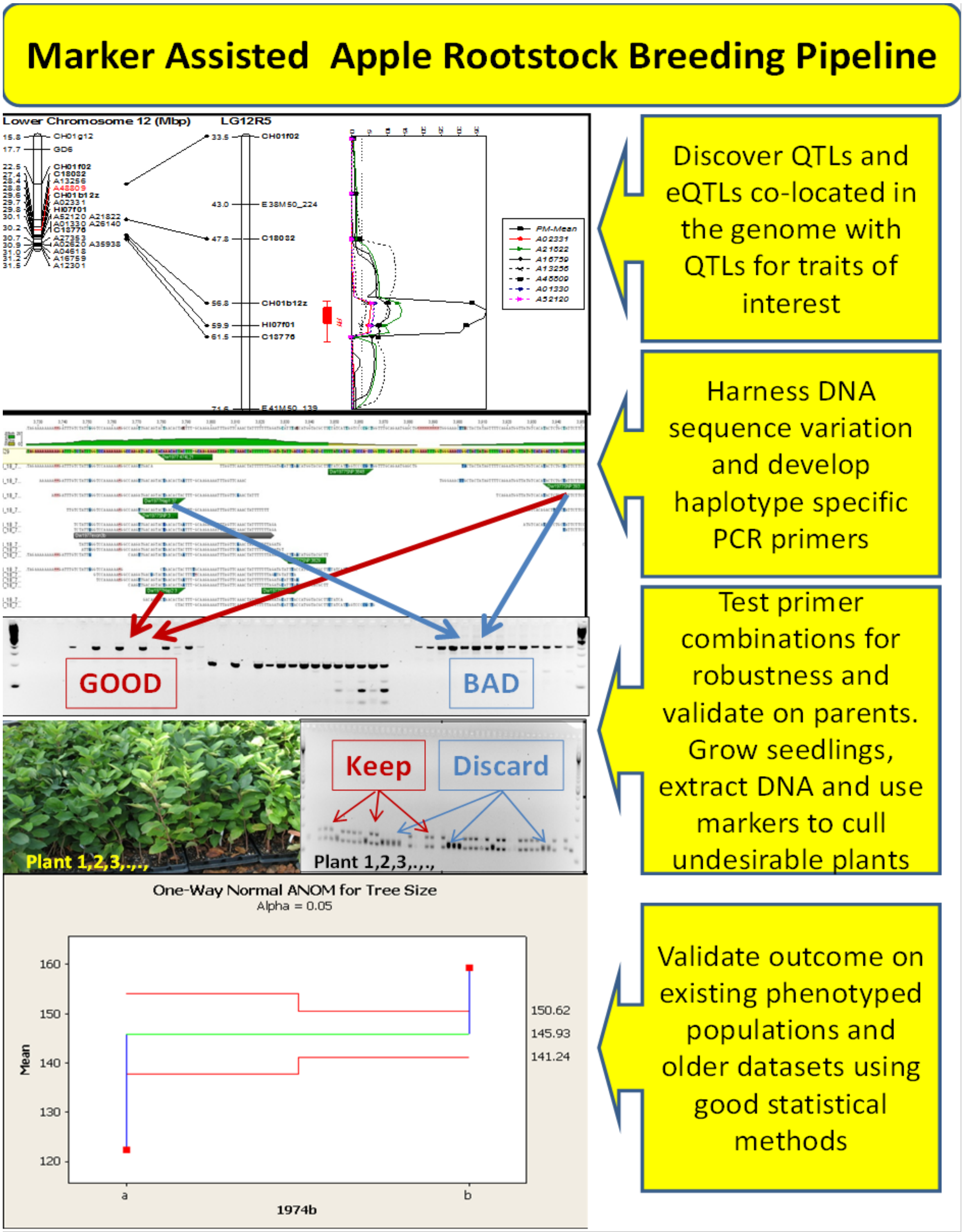
## Treatments and Diagnostics Possible with Aeroponics

Integration with robotics will allow multiple automated diagnostics and treatments

- Mineral nutrients
- pH
- Temperature (cold or heat shock) with the addition of a transducer
- Plant growth regulators
- Root pathogens
- Salinity
- Drought

- Easy access roots – RNA, gene expression
- Root growth
- Architecture
- Genotype specific root metabolites
- Disease resistance
- Nutrient induced architecture
- Root gas exchange and respiration

Appendix Figure 3. Examples of treatments and diagnostic measurements possible with aeroponic systems.




Appendix Figure 4. Marker assisted breeding pipeline in the Geneva breeding program.

# 2019-2020 FUTURE RESEARCH

1. Evaluation of New Postharvest Fungicides for Pome Fruits – Dr. Jim Adaskaveg
    a. Part of Dr. Adaskaveg's research in 2018-2019 will include a component specifically focused on organic controls of fire blight
2. Postharvest Quality and Physiology of 'Gala,' 'Granny Smith,' and 'Fuji' Apples Subjected to Phytosanitary Irradiation - Dr. Anuradha Prakash
3. Study on Mechanically Mass Harvesting of Cling Peaches and Pears (apples are included) - Dr. Stavros Vougioukas
4. Apple Rootstock Breeding Program Field Trails[2] - Dr. Gennaro Fazio

| 2019/2020 | AMOUNT |
|---|---|
| Jim Adaskaveg - Evaluation of new bactericides for control of fireblight… | $23,000[1] |
| Anuradha Prakash - Postharvest Quality and Physiology… | $1,500[2] |
| Stavros Vougioukas - Study on Mechanically Mass Harvesting… | $2,500[3] |
| Gennaro Fazio - Apple Rootstock Breeding Program Field Trails… | $0[4] |
| Fiscal Impact for 2019/2020 | $27,000 |

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[1]Research done by Dr. Adaskaveg will be done on both organic and conventional apples.

[2]This amount was donated by the California Apple Commission for apples that will be used in the study.

[3]The CAC has partnered with the California Pear Advisory Board for this research project. The research includes apples and is applicable to our industry as well.

[4]The CAC has partnered with the Cornell University/USDA-Agricultural Research Service Apple Rootstock Breeding Program to conduct field trials of Geneva rootstocks in California in the spring of 2020.

AES/CE MAR 84

Workgroup: Apple
Department: Plant Pathology/UCR

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

Project Year: 2019-20 Anticipated Duration of Project: 5th year of 5 years

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

Project Title: Evaluation of new biological controls for management of fire blight of apples caused by *Erwinia amylovora* and evaluation of new natural products as organic postharvest fungicides for pome fruits

Keywords: Biological control, natural products, organic treatments

**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 disease is indigenous to North America but has spread worldwide. In the spring, flowers are infected through natural openings in nectaries and pistils. From there, the bacteria spread into the peduncle, spur, and twig where it causes a canker. During warm, humid weather, ooze droplets consisting of new inoculum are exuded from peduncles and other infected tissues. Inoculum is spread by wind, rain, insects, birds, or by contaminated pruning tools. Secondary infections may occur throughout the growing season. The pathogen overwinters in cankers, flower buds, and diseased fruit.

Current chemical control programs for fire blight are based on protective schedules using available compounds that are best used as contact treatments. Conventional copper compounds are only effective when disease severity is low to moderate. They may cause fruit russeting and therefore, labeled rates are at low amounts of metallic copper equivalent (MCE) that are at the limit of effectiveness. New re-formulated copper products that can be used at reduced MCE rates and that cause less phytotoxicity are available. Some products are OMRI-approved including Badge X2, CS-2005, and Cueva. Among these, Cueva has been often more effective without causing phytotoxicity. Contributing to the low efficacy of copper is that low to moderate levels of copper insensitivity in pathogen populations has been detected in our surveys. Because only few treatments are permitted for organic apple production, research on OMRI-approved copper and other products needs to be continued. We identified copper-enhancing compounds such as the experimental SBH that can be added to copper to increase its activity so that the treatment can be more effective at low copper rates that do not cause phytotoxicity. We plan to continue to evaluate these compounds if they are made available again by potential registrants.

The antibiotics streptomycin and oxytetracycline can only be used in conventional pome fruit production. The incidence of resistance to streptomycin in California orchards has been fluctuating from very high to low in our surveys between 2006 and 2018. Reduced sensitivity to oxytetracycline has only been found sporadically, and these isolates did not persist. However, in 2018 we detected highly resistant strains at two locations. Results of 2019 surveys are currently pending and will show if resistant populations persist at these locations. The mode of action of resistance will need to be investigated to possibly determine its origin. Kasugamycin (Kasumin) is now registered in California, but currently not as an organic treatment. Because it is organically produced by fermentation, it is in the process of being submitted to the NOSB for approval as an organic treatment. Resistance in *E. amylovora* has not been found to date among hundreds of strains evaluated from different pome fruit growing areas in California.

The biocontrol treatments Blight Ban A506 (*Pseudomonas fluorescens* strain A506) and Bloomtime Biological (*Pantoea agglomerans* strain E325), and the fermentation product of *Bacillus subtilis* Serenade (strain QST 713) have been inconsistent over the years in their performance in our trials and were most effective under low inoculum levels and less favorable micro-environments. Serenade, using the new liquid formulation ASO showed greater efficacy in mixtures with copper. Research will need to be continued with new copper products or other additives. The biocontrol Blossom Protect (*Aureobasidium pullulans*) has been very effective under less to moderately favorable disease conditions, and it is one of the most consistent biologicals that we have evaluated. It also performed very well in 2019 under high disease pressure. Possibly, the new buffer additive enhanced its efficacy. Biocontrols are most effective when they are actively growing on the plant. Several mechanisms have been described for biocontrol agents that lead to the control of the pathogenic agent including: (1) Competition; (2) Antibiosis or biochemical inhibition; (3) Site exclusion; (4) Parasitism; and (5) Systemic-acquired resistance. Thus, another aspect of our organic research that we have been working on is to enhance the growth of biologicals by adding nutrients to the tank mixture just prior to application. Growth enhancers tested to date have been inexpensive and have sometimes resulted in improved performance by favoring growth of the biocontrol organism as compared to the pathogen. The goal will be to test these growth enhancers in selected combinations and ultimately to use them in a rotation program.

We are also evaluating other bactericide alternatives such as the natural fermentation compounds lactic acid, ε-poly-L-lysine, and nisin that have known anti-bacterial activity and are used as US-FDA-approved food preservatives. They potentially could qualify as biopesticides with the EPA and ultimately as organic compounds with the NOSB and OMRI. Our initial evaluations with these compounds showed high toxicity in in vitro studies, but only moderate activity in the field. Therefore, we continue to try to improve their efficacy by using selected additives. We are currently consulting with a formulation chemist with a major registrant on ways to formulate ε-poly-L-lysine, and nisin. Our goal is to develop effective rotational programs for organic farming practices with the use of copper and biologicals as well as conventional programs with the use of antibiotics, copper, biologicals, and other bactericidal compounds for use during bloom and early fruit development.

Toxicity of some copper and sulfur products has been shown to some of the new biocontrols used in fire blight management. Copper is generally incompatible with bacterial biological controls, but compatible with yeast-based products. Sulfur is toxic to both fungal and bacterial biologicals. Testing needs to be extended among the biologicals, and different formulations of copper products need to be included. Liquid lime sulfur has activity against fire blight, however, it is phytotoxic to blossoms and is used for chemical thinning. We plan to evaluate low rates of copper in mixtures with yeast (fungal) biocontrols and organically-approved antibacterial products such as lactic acid, poly-L-lysine, and nisin that are currently used in the food industry and preservatives.

In research in 2017, use of the OMRI-approved LifeGard (Certis) to complement copper and other control materials as a systemic acquired resistance (SAR) treatment was unsuccessful. The non-organic compound acibenzolar-S-methyl (Actigard) was shown to be inconsistent in previous trials. In 2018, we initially evaluated a novel way to inhibit bacterial pathogens by the interference with vital processes such as the secretion of pathogenesis-related proteins. For this, the type III secretion system is used by many bacterial plant pathogens, and inhibitors of this mechanism (coded TS products) may interfere with the pathogens ability to enter the plant. These products may potentially be registered as organic compounds.

In a recent international fire blight meeting, information was discussed concerning the pending registration of several new products that use mixtures of bacterial phages for controlling the *E. amylovora* population levels. In research done by others, mixtures of the phages with other biological controls such as *Aureobasidium pullulans* (e.g., Blossom Protect) gave a higher level of control than using either product alone (i.e., phages or *A. pullulans*). Our goal is to develop effective rotational programs for organic farming practices with the use of copper, biologicals, and innovative strategies such as registering kasugamycin, food preservatives, and potential phages as OMRI approved natural products. We also will work on conventional programs with the use of antibiotics alone or in mixtures with copper, biologicals, or natural products during bloom or as cover sprays during early fruit development.

***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 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. In California the former three are most common. There is a deficiency of postharvest biocontrols and natural products that are available to prevent decays in storage. BioSave 100 is one of the only materials currently available in the United States, but it is not very effective. Other products like Aspire have been discontinued. Still, new biological products have been registered in other countries.

In our studies on natamycin we demonstrated that the food preservative is effective against a spectrum of postharvest pathogens including those causing gray mold, Rhizopus rot, Mucor rot, and Alternaria decays, but it was not highly effective against blue mold on apples, apple-pears, and pears. Natamycin was registered as the biopesticide BioSpectra 100SC on stone fruit and citrus but not pome fruit. This fungicide has been federally-approved by the US-Food and Drug Administration (FDA) as a food additive to prevent mold growth, including

*Penicillium* species, on dairy (e.g., cheese and yogurt) and meat products for many years in the United States. Over all the years in use, resistance in *Penicillium* species against natamycin has not occurred. Working with DSM, the producer, and Pace International, the registrant, we submitted a letter of support to the NOSB for approval of natamycin as an organic postharvest treatment of pome fruits. Currently natamycin is exempt from tolerance by the US-Environmental Protection Agency (EPA). Therefore, our goal is to continue to evaluate natamycin and other new postharvest fungicides for the management of postharvest decays of apples.

**Objectives for 2019-20**

***Fire blight research***

1. Evaluate the efficacy of treatments for managing fire blight.
   - A. Evaluate growth enhancers (e.g., buffers) of biological control agents in lab and field trials.
   - B. Laboratory in vitro tests on copper and zinc products with newly identified antibacterial, food additives (lactic acid, Ɛ-poly-L-lysine, and nisin), new biologicals, and experimental compounds.
   - D. Field trials with protective air-blast spray treatments:
     - i. Kasugamycin in combination with organic treatments to support organic petition to NOSB.
     - ii. New formulations of copper (e.g., Badge X2, CS-2005, Cueva), zinc, food additives (lactic acid, poly-L-lysine, and nisin), and biologicals (e.g., Serenade ASO) in combination as a new antibacterial strategies.
     - ii. Biological treatments (Blossom Protect, Serenade) with and without the addition of growth enhancers and copper.
     - iii. Use of bacterial phage-mixture products with other biological control treatments (i.e., Blossom Protect) to provide an integrated strategy.

***Postharvest research***

2. Comparative evaluation of new postharvest fungicides
   - A. Evaluate natamycin (BioSpectra) and other new postharvest fungicides such as Academy at selected rates against gray mold, blue mold, Alternaria decay, and bull's eye rot and compare to fludioxonil.
   - B. Evaluate mixtures of these compounds and new formulations of natamycin to improve performance of the fungicide.

**Plans and Procedures**

***Laboratory assays and small-scale field trials to evaluate the efficacy of treatments for managing fire blight.*** In laboratory assays we will evaluate new copper and zinc products, as well as copper-enhancing compounds (e.g., SBH) and newly identified antibacterial, food additives such as lactic acid, poly-L-lysine, and nisin) will be evaluated for their toxicity to *E. amylovora* in laboratory assays. Growth will be compared between non-amended and amended media, and the most effective additives will be selected for field trials.

In small-scale field tests in an experimental orchard, treatments using the copper products Badge, CS-2005, and Cueva, and the biological treatments Blossom Protect, and Serenade, will be applied to during bloom using small field sprayers. Treatments with biological control agents will also be mixed with growth enhancers; whereas copper treatments will be mixed with newly identified, food grade-additives (e.g., lactic acid, poly-L-lysine, and nisin) based on laboratory results. Additionally, Type III secretion inhibitors (TS products) may also be evaluated based on availability. After a selected time, 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 replication.

***Field studies on the management of fire blight using protective treatments during the growing season.*** Air-blast sprayer field studies on the relative efficacy of protective treatments will be conducted in an experimental apple orchard at KARE and UC Davis. Four applications will be done (at pre-bloom, 10-20%, 60-80% full bloom, and petal fall). The relative efficacy of protective treatments (Kasumin, Badge X2, CS-2005, Cueva, Blossom Protect with the newly formulated buffer, Serenade), as well as of selected food grade-additives (e.g., lactic acid, poly-L-lysine, and nisin) based on laboratory results will be evaluated alone or in selected mixtures to develop integrated programs for resistance management. Additionally, two companies are willing to provide new bacterial phage-mixture products and they have suggested integration with treatments with *Aureobasidium pullulans* (i.e., Blossom Protect). For this, we will initially follow recommended guidelines from the registrant and we are currently cooperating with one company by providing strains of the pathogen from California to select phages that are possibly more specific for these strains. Incidence of new blight infections on blossoms and leaves in addition to potential phytotoxic effects of the treatments (e.g., fruit russeting) will be evaluated. Application timings will be determined based on temperature, rainfall, and host development. Treatments will be replicated four to eight trees. Data for chemical and biological control will be analyzed using analysis of variance and LSD mean separation procedures of SAS 9.4.

***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 (*P. expansum, B. cinerea, Alternaria* sp.) and treated after selected times. Natamycin (BioSpectra 100SC) and other formulations of the fungicide (e.g., high solubility) will be evaluated by themselves and in mixtures with other fungicides (e.g., fludioxonil) in experimental packingline trials at Kearney Agricultural Center at selected rates. Four replications of 20-40 fruit per rep of will be used. For the new fludioxonil-difenoconazole pre-mixture (i.e., Academy), we will compare the efficacy of different application methods (in-line drench, CDA, and T-Jet). Treatments will be compared to fludioxonil. Data will be analyzed using analysis of variance and averages will be separated using least significant difference mean separation procedures of SAS 9.4.

**Benefits to the industry**

***Fire blight research.*** With removal of antibiotics as treatments for organic production due to their use in human medicine and animal agriculture, research on organic alternatives are desperately needed for apple production. Because kasugamycin is not used in human medicine or veterinary science, has a different MOA from other antibacterial products, and is organically produced by fermentation, this pending submission is supported by the registrant (UPL) to the NOSB for approval as an organic treatment. Furthermore, with the limited number of materials available to organic pome fruit growers, new active ingredients that are OMRI approved are needed for managing fire blight in an integrated approach. Our research project has identified biologicals with consistent and inconsistent performance and growth enhancers that may improve their overall performance. Information from this research project will help to develop integrated programs using rotations or mixtures of organic compounds (e.g., copper), biologicals (Serenade, Blossom Protect, etc.), food-grade, antibacterial additives, phage mixtures, and possibly Type III secretion inhibitors to effectively manage the disease. Thus, we are testing innovative solutions for managing fire blight potentially without antibiotics for the organic apple industry. This information is being posted on the UCIPM website and in apple industry newsletters.

***Postharvest decay management research.*** 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 for apple need to be developed and continually adapted based on new organically-certified fungicides that will allow rotations and mixtures to optimize control of postharvest fungal pathogens. The development of several effective postharvest fungicide treatments including materials that are exempt from tolerance (i.e., natamycin), NOSB approved polyoxin-D, and potential NOSB and OMRI -certified treatments (i.e., natamycin) will improve performance and greatly decrease losses of fruit from various decays during storage in a durable program that will be effective for many years. Thus, information from this research directly benefits growers and packers by identifying and registering new materials, as well as development of improved application practices for control of postharvest diseases of apples.

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**Budget Request:**
Budget Year: 2019-2020.
Funding Source: ____________ Apple Commission of California ____________

| | | | |
|---|---|---|---|
| Salaries and Benefits: | Post-Docs/SRA | | 5,000 |
| | Lab/Field Ass't | | 1,000 |
| | Subtotal | | 6,000 |
| | Employees' Benefits | | 3,500 |
| | | Subtotal | 9,500 |
| Supplies and Expenses* | | | 12,000 |
| Equipment | | | 0 |
| Operating Expenses/Equipment Travel (Davis Campus only) | | | 0 |
| Travel | | | 1,500 |
| Department Account No. ________ | | **Total** | **23,000** |

* - Costs include expenses of $12,000 for maintaining an apple orchards at the Kearney AgCenter.

Originator's Signature: J. E. Adaskaveg ____________ Date: 7-30-2019

Department Chair: Katherine Borkovich ____________ Date: 7-30-2019

Liaison Office: ____________ Date: ____________

Project Leader: Dr. Anuradha Prakash

Mechanism of low-dose irradiation on expression of genes involved in ethylene biosynthesis in 'Granny Smith' apples

**2019-2020 Research:** Our next steps are to conduct a comparative analysis of Granny Smith apples treated with irradiation and 1-MCP and DPA (as inhibitors of scald) and methyl bromide (as a phytosanitary treatment) and explore the differences in mechanism of action.

Superficial scald is a physiological disorder characterized by skin browning that appears during or after storage of 'Granny Smith' apples. The mechanism for scald development is not fully understood, but it is hypothesized that scald formation is related to increased ethylene production. In apples, low dose irradiation induced ethylene reduction appears to be directly related to prevention of superficial scald. However, the molecular basis of such an irradiation-induced effect is not known. In this study, effort was made to better understand the molecular basis of the decrease in superficial scald and ethylene production in 'Granny Smith' apples after treatment with x-ray irradiation. Apple fruit were exposed to x-ray irradiation treatment either at 310 Gy or 1000 Gy and ethylene production, ACC oxidase enzyme activity and expression of the genes responsible for ethylene biosynthesis were measured after 0, 90, and 180 days of storage plus 7 days at room temperature. Ethylene production of irradiated apples was lower compared to control ($P<0.05$). No difference was observed in ACC oxidase activity at day 0, but irradiation at 310 Gy and 1000 Gy reduced enzyme activity at days 90 and 180 ($P<0.05$). Irradiation treatment reduced the expression of ACS1 and ACO1 ethylene biosynthesis genes ($P<0.05$), which had a high correlation with ACC oxidase enzyme activity. Irradiation did not have a significant effect on other ethylene biosynthesis genes ACS3 and ACO2. Irradiated apples also exhibited lower expression of α-farnesene synthase gene expression. Thus inhibition of scald was related to suppression of gene expression of key enzymes involved in ethylene biosynthesis as well as production of α-farnesene by irradiation. Further analysis of results is pending to determine if irradiation induced reactive oxygen species also inactivate the enzymes directly.

Our next steps are to conduct a comparative analysis of Granny Smith apples treated with irradiation and 1-MCP and DPA (as inhibitors of scald) and methyl bromide (as a phytosanitary treatment) and explore the differences in mechanism of action.

**Acknowledgements:** We would like to thank Todd Sanders and Elizabeth Carranza of the California Apple Commission, Jeff Columbini of Lodi Farming and Tim Sambado of Prima Fruitta for information and the apples and Steri-Tek for carrying out the irradiation treatment. This project was supported with funding from a USDA-TASC grant.

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OFFICE OF RESEARCH
Sponsored Programs
1850 Research Park Drive, Ste. 300
Davis, CA 95618-6153

Telephone: 530.754.7700
Facsimile: 530.752.0333
E-Mail: proposals@ucdavis.edu

November 29, 2018

Rachel Elkins, Liaison Officer
European Pear Research Advisory Committee Chair
UC Cooperative Extension
833 Lakeport Blvd.
Lakeport, CA 95453

**Proposal entitled: ............... "Study on Mechanical Mass-Harvesting of Pears"**
**Principal Investigator: ........ Stavros Vougioukas**

Dear Ms. Elkins:

On behalf of The Regents of the University of California, Davis Campus it is our pleasure to present for your consideration the above-referenced proposal.

Please contact me with any administrative questions. We request correspondence pertaining to this proposal be sent via email to proposals@ucdavis.edu or mailed to the Office of Research Sponsored Programs Office, 1850 Research Park Drive, Suite 300 Davis, CA 95618-6153.

We look forward to working with you on this important project.

Sincerely,

Marlene Mooshian
~~Contracts and Grants Analyst~~

**Please refer to Proposal No 19-2336 on all future correspondence.*

**Send Award Notice to:**
Office of Research, Sponsored Programs
1850 Research Park Drive, Suite 300
University of California
Davis, California 95618
awards@ucdavis.edu

**Send Checks (Payable to The Regents of the University of California) to:**
Cashier's Office
University of California Davis
PO BOX 989062
West Sacramento, California 95798-9062

University of California, Davis

**PROJECT PLAN/RESEARCH GRANT PROPOSAL**

Project Year: 2019 Anticipated Duration of Project: 3 Years
Project Leader: Stavros Vougioukas (Dept. of Biological & Agricultural Engineering) Location: UC Davis
Cooperating Personnel: Elizabeth Mitcham (Dept. of Plant Sciences, UC Davis), Rachel Elkins (Farm Advisor, UC ANR)
Project Title: Study on Mechanical Mass-Harvesting of Pears
Keywords: Harvesting, Productivity, Mechanization
Commodity(s): 'Bartlett' Pear Relevant AES/CE Project No.

**Problem and its Significance:**
Harvesting is one of the most labor-intensive operations in pear production. A 2012 UC ANR pear production cost report estimated the manual harvesting cost for green Bartlett pears at $1,239/acre, using $11.20 per hour for general labor (Elkins, Klonsky, Tumber, 2012). This translated to 85% of the total harvest cost, which includes hauling to the packinghouse, and 13% of the total operating cost, per acre. Labor cost will increase significantly due to recent legislation. The greatest problem though, is that in addition to cost, supply of skilled pickers is decreasing; hence, risk of losing crop is increasing too. Therefore, pear growers face a great need for mechanical harvesting solutions.

**Objectives:**
The proposed research aims to investigate a novel approach to intercepting pears during a shake-and-catch operation. The main idea is to design, build and test a prototype system that inserts multiple catching surfaces (e.g., soft rods) into the canopy during shaking, and effectively reduces pear damage during shaking and falling. The envisioned system would be compatible with existing tree shaking operations and equipment, if with minor modifications. Rod insertion systems have been tried in the past for fruits like apples (Millier et al., 1973), plums and pears (Mehlschau et al., 1977), with promising results. Also, simulations performed in the Bio-Automation Lab based on models of pears and cling-peach trees (funding from Pear Advisory Board, Cling Peach Mechanization Fund, USDA-NIFA) have confirmed that properly deployed multi-level rods that penetrate into the canopy can intercept up to 90% of falling fruits (Munic et al., 2016). Our objective is to utilize seed funding provided by this grant and possibly by other commodity boards (a pre-proposal was submitted to the CA Cherry Board) to design prototypes and gather preliminary data that will enable the submission to USDA-NIFA of a large, multi-state Specialty Crops Research Initiative (SCRI) proposal focused on mechanical tree fruit harvesting.

**Plans and Procedures:**
**Year 1:** Four objectives will be pursued. We will compile a detailed literature review of systems developed in the past and analyze their pros and cons (1). Alternative catching surface designs and insertion mechanisms will be explored (2) and some will be fabricated and tested in the lab (3). Alternative designs will include canopy-penetrating inflatable rods and rigid-padded rods with inflatable sides. Controlled pear fruit drop experiments will be performed, and the fruit-rod interaction will be analyzed. The goal is to have an SCRI mechanical harvesting pre-proposal submitted in fall 2017 (4).

**Year 2:** A full-size insertable rod will be fabricated and tested in the lab via controlled fruit drop experiments to: optimize parameters such as side-finger length, diameter, material thickness, inflation pressure, and finger curling curvature (Objective 1); implement a mechanism for rod extension, retraction and possibly segmentation to reduce overall rod length (Objective 2). Canopy penetration experiments will take place in orchards to assess insertable rod engagement with canopies and fruits (Objective 3).

**Year 3:** A half-size prototype of multi-level insertable rods will be fabricated and actuation and control systems for its operation will be developed (Objective 1). The prototype will be tested in orchards (Objective 2). This will require access to a tree shaker (like a COE C7-E), collaboration with pear growers, and collaboration with the post-harvest center to assess postharvest fruit quality (objective 3).

**References:**


Elkins, R., Klonsky, K., Tumber, K. 2012. SAMPLE COSTS TO ESTABLISH AND PRODUCE PEARS. Un. of California Cooperative Extension.

Mehlschau, J., Fridley, R., Brazelton, R., Gerdts, M. and Mitchell, F., 1977. Mechanical harvester for fresh-market plums. California Agriculture, 31(3), pp.11-11.

Millier W. F., Rehkugler G. E., Pellerin R. A., Throop J. A., Bradley R. B. (1973). Tree Fruit Harvester with Insertable Multilevel Catching System. *Trans. ASABE* 16(5), 844-850.

Munic, J.P., Vougioukas, S.G., Arikapudi, R. (2016). A Study on Intercepting Falling Fruits with Canopy Penetrating Rods. 2016 ASABE Annual International Meeting. Paper Number 162456923, Orlando, Florida.


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**BUDGET REQUEST**

Budget Year: 2019

Funding Source: California Pear Advisory Board

| | | |
|---|---|---|
| Salaries and Benefits | | |
| Development engineer – Dennis Sadowski (20%) | | $14,686 |
| Subtotal | Sub 2 | $14,686 |
| Employee Benefits | Sub 6 | |
| Development Engineer | | $7,710 |
| | SUBTOTAL | $22,396 |
| Supplies and Expenses<br>Electronic, mechanical, pneumatic components. Fruit quality assessment. | Sub 3 | $8,000 |
| Equipment | Sub 4 | |
| Travel | Sub 5 | $1,500 |
| | TOTAL | $31,896 |

Notes:

| | | | |
|---|---|---|---|
| | _______________ Originator's Signature | Date | ________ |
| COOPERATIVE EXTENSION | County Director _______________ | Date | ________ |
| | Program Director _______________ | Date | ________ |
| AGRICULTURAL EXPERIMENT STATION | Department Chair _______________ | Date | ________ |
| LIAISON OFFICER | [signature] Marlene Mooshian, Contracts and Grants Analyst<br>Office of Research - Sponsored Programs | Date | November 29, 2018 |

D2454-2(1/84)
(Rev. 9/96)

**Internal UCD Document: Budget Justification**

**PERSONNEL**

**Dr. Stavros Vougioukas - PI:** Will work a 5% calendar month effort in year one on a cost-share basis. Will be the principal PI responsible for the project. He will work closely with the Senior Design Engineer to guide the design, and testing of prototypes.

**Dennis Sadowski – Research and Development Engineer III (7120):** Will work 20% under the direct supervision of Dr. Vougioukas to design, fabricate, and test prototypes for intercepting falling fruits.

**BENEFITS**

Fringe Benefits are calculated using the UC Davis composite rates developed by the UC Davis Costing and Policy office as required per institutional policy and reflected in the UC Davis federally negotiated rate agreement dated August 2018. Rates are applied by title code and fiscal year.
http://afs.ucdavis.edu/our_services/costing-policy-e-analysis/composite-benefit-rates/

**TRAVEL**

Funds are requested to travel within California for experiments in commercial orchards, and for renting a truck.

**OTHER DIRECT COSTS**

*Materials and Supplies*

Various electronic, mechanical, and pneumatic components.

**INDIRECT COSTS**

There are no indirect costs associated with this proposal.

**Apple Rootstock Breeding Program Field Trial Study**

**Future Activities Summary**

*Project Summary*

The U.S. apple industry features 244,000 acres of orchards which produce 240M bushels each year with a farm gate worth of almost 4 billion dollars. Apple rootstocks are the foundation of a healthy and productive apple orchard. They are the interface between the scion and the soil, providing anchorage, water, nutrients, and disease protection that ultimately affect the productivity and sustainability of the orchard. Dwarfing and early bearing apple rootstocks provide unique advantages in fruit growing as they increase the efficiency of fruit production by making the orchard amenable to high density and automated or mechanically assisted operations. Most commercial dwarfing apple rootstocks being used by the U.S. industry are susceptible to devastating diseases (fire blight, apple replant disease, viruses), can be intolerant to other abiotic stresses (cold, drought, nutrient deficiencies, poor water quality) and may not be physiologically compatible with existing grafted scion varieties. This research project concerns breeding and evaluation of improved apple rootstocks and developing an understanding of the genetic and physiological components of apple rootstock traits. In cooperation with other USDA units, universities, and private concerns, the project aims to develop and release improved apple rootstocks and apply genomic, phenomic and bio-informatic tools for marker assisted breeding of apple rootstocks while leveraging discoveries in plant nutrition and root morphology. Research work in greenhouse, laboratory, nursery, and field plots, whether located at the PGRU or at cooperators' facilities, will be used to evaluate the characteristics of interest and examine new rootstock selections for commercial adaptation. The project utilizes cost efficient state of the art technologies to understand how rootstocks can make the orchard more productive and apply such knowledge to develop improved rootstocks. This research impacts all U.S. apple producing regions, with the potential to improve productivity, safety and survivability of apple orchards by 10% to 20% when new rootstock technologies are implemented, and increasing labor efficiency by enabling mechanization of cultural practices.

*California Field Trials*

In April of 2019, Dr. Gennaro Fazio from the Plant Genetic Resources Unit at USDA-Agricultural Research Service based at Cornell University, visited the CAC Board of Directors. The purpose of his visit was to discuss the potential opportunities for the California apple industry to explore the use of Geneva rootstocks. As a result of this visit, Dr. Fazio, reaching out to the industry with an opportunity to plant field trials utilizing new rootstocks in California. With the assistance and collaboration of Sierra Gold, the Apple Rootstock Breeding Program was able to secure roughly 840 trees to be planted at two different locations in California. The trees will be both Granny Smith and Gala varieties as these are familiar to the California industry at this point in time. The trials will begin in the spring of 2020, and a report of the trial results will be disseminated to the industry accordingly.

# APPLE EDUCATION

# APPLE EDUCATION SUMMARY

The California Apple Commission strives to provide educational information for classrooms throughout California. Throughout 2019, the California Apple Commission disseminated informational fact sheets, coloring pages, and other information specific to California apples to the California Foundation for Agriculture in the Classroom. The Foundation provides educational resources for students and facilitates outreach to California teachers and their students who have an interest in California agriculture.

The Commission's goal through the educational sponsorship is to create agriculture awareness in classrooms and create a basis for the appreciation of the importance of agriculture in the everyday lives of students. The Commission will continue to make a positive impact on the way students view agriculture and the world around them.

The Foundation provides informational guides for a variety of agriculture commodities. Their website provides books and videos for students, as well as pamphlets, lesson plans, and informational fact sheets for teachers to use in their classrooms. The learning materials provided on their website are created with all grade levels in mind, assuring the most effective learning material. The California Foundation for Agriculture in the Classroom foundation also funds scholarships and grant opportunities for students in the agriculture industry. To learn more about what the Foundation has to offer, please visit their website: http://learnaboutag.org/index.cfm

The following is the fact sheet that the California Foundation for Agriculture in the Classroom provides on their website for the California Apple Commission. This information will be distributed to schools in California and other educational institutes.

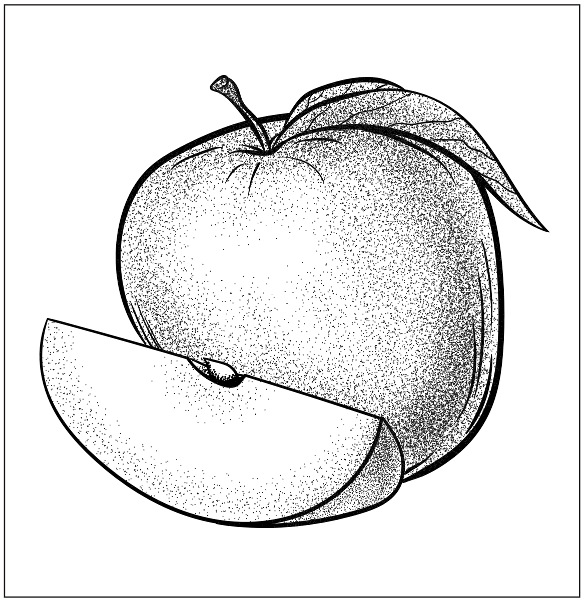
LearnAboutAg.org
California Foundation for Agriculture in the Classroom

*Commodity Fact Sheet*

# Apples

***Information compiled by the California Foundation for Agriculture in the Classroom***

**How Produced** – Grafting, a horticultural technique that joins two plant structures together, is the first step in apple production to ensure that rootstock and varieties will bare fruit. Once planted, it takes four to five years for the tree to produce the first fruit and will produce fruit for up to 100 years. Most apple varieties are self-sterile, meaning unable to pollinate themselves and rely upon cross-pollination. The most commonly used pollinator is crab apples (also known as wild apples) in which pollination takes place in the spring, when trees are in blossom. Once pollinated, blossoms fall to the ground and small apples begin to grow in the blossom's place.



During spring and summer, apple trees require frequent watering. Apple trees can tolerate a great deal of heat if they have sufficient water. The apple crop is harvested by hand in the fall. To insure crop production for the following year, trees must be pruned yearly in the winter to promote new vegetative growth.

**History** – The first documented history of apples dates to 300 B.C. in the Persian Empire, where the cultivation and enjoyment of apples was an essential part of civilized life. In the 1400s apples were rediscovered and in the 1500s regained popularity again as a common commodity. During this time, European settlers of the Americas brought with them their English custom varieties, and the first apple orchard was planted in America. William Blackstone was the first pilgrim to plant apples trees grown in the United States in the Massachusetts Bay Colony in 1629.

In the early 1800s stories began circulating about John Chapman, better known as Johnny Appleseed, who traveled across the Ohio Valley carrying bags of apple seeds. Venturing westward, he planted seeds and grew apple trees wherever he roamed to ensure that settlers living in the western frontier would have nutritious apples to eat. Apples have a place in more recent history, too. In 1962, the first American to orbit the Earth carried pureed applesauce to consume during the flight.

**Varieties** – The apple, scientifically known as Malus domestica, is a member of the rose family. California has almost 14,000 acres dedicated exclusively to apple production. California grows four main varieties: Gala, Fuji, Granny Smith, and Cripps Pink. Within the United States, roughly 2,500 varieties of apples are grown. The top 10 apple varieties grown within the United States are Red Delicious, Golden Delicious, Fuji, Granny Smith, Rome Beauty, McIntosh, Idared, Jonathan, Gala, and York Imperial.

**Commodity Value** – The United States' 7,500 apple producers grow approximately 240 million bushels of apples each year on 322 thousand total acres of land. The wholesale value of the United States apple crop is approximately $4 billion annually. Worldwide, the United States ranks second to China in apple production. California ranks fourth in U.S. apple production, generating 12 percent of the national apple crop which is approximately 800 million pounds annually. Seventy-five percent of the apples produced in California will be shipped domestically and 25 percent are exported. Canada, Malaysia, Mexico, Taiwan, and Panama are five of the 27 global destinations California exports to.

**Top Producing Counties** – There are five major regions in which apples are grown in California. Historically, apple production was limited to the coastal mountains, the Sierra foothills, and in the Southern California mountains. Recently apple production has expanded into the Central Valley with new plantings of Granny Smith, Fuji, Gala, and other varieties. Important coastal apple producing counties are Sonoma, Santa Cruz, and San Luis Obispo. The major apple production areas are in the San Joaquin Valley with Kern, Fresno, San Joaquin, and Madera counties being the leading producers.

**Nutritional Value** – One medium-sized apple provides 20 percent (five grams) of the daily requirement for dietary fiber, eight percent of the daily requirement for vitamin C, and is a healthful source of potassium. One apple has approximately 80 calories and contains no fat, cholesterol, or sodium.

**For additional information:**
California Apple Commission
Phone: (559) 225-3000
Website: calapple.org

CALIFORNIA APPLE COMMISSION

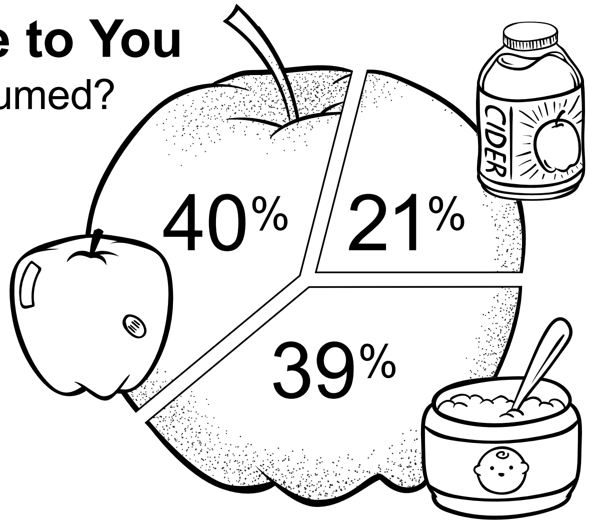


This is one in a series of fact sheets composed by the California Foundation for Agriculture in the Classroom (CFAITC). For additional educational materials: CFAITC, 2300 River Plaza Drive, Sacramento, CA 95833-3293 • (916) 561-5625 • (800) 700-AITC • Fax: (916) 561-5697
Email: info@learnaboutag.org • Website: LearnAboutAg.org ©2018 California Foundation for Agriculture in the Classroom. All rights reserved.

# Apples Activity Sheet

## From Apple Tree to You

How are apples consumed?




### *Lesson Ideas*

- Dissect and examine the anatomical parts of an apple. Observe and identify the function of each structure.
- Research and explain the aphorism "an apple a day keeps the doctor away" using nutritional information.
- Observe and practice various grafting techniques used to grow apples.
- Compare hand and machine harvesting methods. Invent a harvesting machine for apples.
- Perform experiments that show the different methods of preserving apples.
- Research and determine what the top ten apple varieties are and why they are most popular amongst consumers.
- Calculate the percentage of water weight in apples by dehydrating the fruit.
- Sprout an apple plant from a seed.

### *Fantastic Facts*

1. The crabapple is the only apple native to North America.
2. Apples are propagated by two methods: grafting or budding.
3. The apple variety "Red Delicious" is the most commonly grown apple variety worldwide.
4. Apples are a member of the rose family.
5. Twenty-five percent of an apple's volume is air, which makes it naturally buoyant.
6. It takes the energy from 50 leaves to produce one apple.
7. World's top apple producers are China, United States, Turkey, Poland, and Italy.
8. Archeologists have found evidence that humans have been enjoying apples since 6500 B.C.
9. Apples account for 50 percent of the world's deciduous fruit tree production.
10. Two-thirds of an apple's fiber and antioxidants are found in the peel.

### *Lesson Plan: Sugar or Starch*

**Introduction:** Apples naturally contain starch also known as carbohydrates. When an apple begins its ripening process, starches are converted into sugar. This conversion process starts at the core of the apple and moves outward toward the skin. To check the ripeness of the apple an iodine test can be used to identify the amount of starch present.

**Objective:** Students will investigate the ripening process of apples by conducting an iodine experiment.

**Standards:** NGSS: 4-LS1-2, 3-5-ETS1-3; CC ELA: L.W.4-5.7

Materials: Variety of apples, iodine tincture, nitrile gloves, safety goggles, paintbrush, knife, paper plates or towels

**Procedure:**

1. Safety note: Iodine tincture is a hazardous material and should be handled with care. Wash hands after use and avoid contact with the eyes and skin.
2. Place individual, whole apples on labeled plates (1, 2, 3, 4, etc.) and instruct students to observe each apple's size, color, texture, and firmness. Have students hypothesize, based on their previous knowledge, which apples are at peak ripeness.
3. Cut apples in half, displaying both sides of the apples on each labeled plate. Have students observe each apple's internal characteristics.
4. With the paintbrush, evenly apply iodine across the cut surface of each top apple half. Let the apple sit for two minutes. Leave the other apple half untouched as a control to compare changes in each apple.
5. Observe the surfaces of the apples. Large amount of purple indicates high starch/low sugar. Little to no purple indicates low starch/high sugar.
6. Place apples on a continuum from least to most ripe. Make concluding observations.
7. Write a conclusion paragraph on your experimental findings.


This Fact and Activity Sheet was developed by California Foundation for Agriculture in the Classroom in conjunction with California educators and meets the required education standards of the California Department of Education.

# CA GROWN PARTNERSHIP

CALIFORNIA
CA GROWN

California Grown, also known as the Buy California Marketing Agreement (BCMA), is a joint effort of agricultural industry groups representing the products of California's farms, ranches, forests, and fisheries. Working as an advisory board to the California Department of Food and Agriculture, BCMA brings together industry and government resources to increase the awareness, consumption, and value of California agricultural products, helping the state's consumers enjoy the best of the California lifestyle.

California Grown is funded through public and private contributions by the U.S. Department of Agriculture, the California Department of Food and Agriculture, and California agricultural organizations.

The Commission participates as an active member of the California Grown partnership by attending regular board meetings and joining internal committees. Through this partnership, the Commission is able to feature California apples at various events including, California Agriculture Day at the Capitol, the Produce Marketing Association's Fresh Summit Exposition, and many more.

In 2019, CA Grown featured California apples in their "Love, California" campaign designed to showcase the farming aspect of the industry in an effort to build a stronger connection with consumers. The campaign included video and photo assets featuring the California apple cycle from farm to table. The goal of this was to educate consumers on the love and care California apple producers put into their products.

# PEST, DISEASE, & STANDARDIZATION

# PEST, DISEASE, & STANDARDIZATION SUMMARY

The California apple industry continuously strives to produce a healthy and safe product. Through its work in pest, disease, and standardization, the Commission continues to partner with other entities to represent the industry on critical issues.

The Food Safety Modernization Act (FSMA) was signed into law on January 4th, 2011 by President Barack Obama. The purpose of the law mandates the U.S. Food and Drug Administration (FDA) to implement a comprehensive, science-based, preventative control across the food supply. The FSMA rules are put in place to ensure specific actions are taken at each of the following points to prevent contamination. FSMA consists of seven different final rules, listed below. The Produce Safety rule specifically focuses on production practices and ultimately establishes science-based minimum standards for the safe growing, harvesting, packing, and holding of produce. The rule puts more responsibility on farms to protect their crops from contamination by creating requirements for water quality testing, raw manure application, examining grazing areas, employee health and hygiene training, and more. The rule gives special attention to sprouts due to their frequent association with foodborne illness outbreaks.

Compliance dates for this rule are as follows:

**January 28, 2019:** Small businesses (average annual monetary value of produce sold during the previous 3-year period is more than $250,000 but not more than $500,000)

**January 27, 2020:** Very small businesses (average annual monetary value of product sold during the previous 3-year period is more than $25,000, but no more than $250,000)

For more information, please visit the following link to view the most recent publication of the rules for the Food Safety Modernization Act:
https://www.fda.gov/Food/GuidanceRegulation/FSMA/

Please see the following pages for information regarding CDFA's Produce Safety Program for industry members, in addition to more information on the FSMA Produce Safety Rule itself.

Under the Produce Safety Rule, every produce farm must have an individual employed who has completed an FDA-approved Produce Safety Rule Grower Training course. This course provides training to ensure a responsible party employed by the farm understands the required food safety practices.

The Produce Safety Rule Grower Training need only be taken once; however, the certificate of completion belongs to the individual and not the farm.

California Produce Safety Program inspectors will ask to see your designated food safety employee's certificate as part of your on-farm inspection.

**About the Training Program**

Currently, only courses that have been accredited by the Produce Safety Alliance will satisfy the requirement for training under the Produce Safety Rule.

The 7-hour Produce Safety Rule Grower Training course covers the following topics:

- Introduction to Produce Safety
- Worker Health, Hygiene and Training
- Soil Amendments
- Wildlife, Domesticated Animals and Land Use
- Agriculture Water (Part I: Production Water. Part II: Postharvest Water)
- Developing a Farm Food Safety Plan
- Postharvest Handling and Sanitation

The California Department of Food and Agriculture has received funding from the FDA to provide Produce Safety Rule Grower Training courses at a reduced rate. The dates for 2019-2020 are listed here and you can register for courses online at:

https://safefoodalliance.com/events/

| City | Date |
| --- | --- |
| Kingsburg | 2-Aug-2019 |
| Bakersfield | 19-Nov-2019 |
| Stockton | 14-Nov-2019 |
| Kingsburg | 3-Dec-2019 |
| Tulare | 5-Dec-2019 |
| Marysville | 5-Dec-2019 |
| Kingsburg | 9-Jan-2020 |
| Stockton | 16-Jan-2020 |
| Bakersfield | 21-Jan-2020 |
| Gilroy Area | 23-Jan-2020 |
| Santa Maria | 28-Jan-2020 |
| Temecula | 4-Feb-2020 |
| Riverside | 5-Feb-2020 |
| Escondido | 12-Feb-2020 |
| Fallbrook | 13-Feb-2020 |
| Red Bluff | 19-Feb-2020 |
| Merced | 24-Feb-2020 |
| Davis/Winters/Dixon Area | 3-Mar-2020 |
| Tulare | 5-Mar-2020 |
| Chico | 12-Mar-2020 |
| Santa Maria | 17-Mar-2020 |
| Stockton | 26-Mar-2020 |
| Roseville | 9-Apr-2020 |

| | |
|---|---|
| Tulare-Spanish | 16-Apr-2020 |
| SLO | 21-Apr-2020 |
| Oxnard-Spanish | 29-Apr-2020 |
| Oxnard | 30-Apr-2020 |

May 30, 2018

**Re: Produce Safety Program Website**

Dear California Produce Associations:

The California Department of Food and Agriculture is pleased to inform you our new Produce Safety Program (PSP) has launched a website that will serve as a resource to California farmers who must comply with new regulations under the Produce Safety Rule (PSR).

The website, which can be found at www.cdfa.ca.gov/producesafety, includes basic information about the PSP and our efforts to help California produce farmers understand how to comply with the requirements of the PSR under the Food Safety Modernization Act (FSMA).

Our hope is that you will use this website and share it with your grower-members as the official resource for information about PSR implementation in California. Additional information will be added to the site in coming months. Currently, California produce farmers can use the website to learn about mandatory Produce Safety Rule Grower training that is required of at least one employee on every produce farm. Our website provides access to registration information for several courses being offered throughout the state that are subsidized by the U.S. Food and Drug Administration so that farms can complete the required training at a reduced price.

The site provides California produce industry members with some initial information about the upcoming PSP inspections that will be conducted by our staff on behalf of the FDA beginning in spring of 2019. To prepare for inspections, the Department is offering on-farm readiness reviews. Growers can schedule a review directly from the website. A Frequently Asked Questions section has been developed, along with some talking points that can be used to explain the new program to consumers. A regular blog is also part of the website and will be used to provide updates on program activities and resources.

In addition to the website, a Facebook page has been created for the program under @CDFAProduce Safety. Interested industry members can also join a mailing list to receive updates and information.

It is estimated over 20,000 farms in California are covered under the PSR, and we will need your assistance in reaching this audience with important information about the new regulation. We encourage your organization to share these new resources with your membership. We also welcome any questions you may have.

Sincerely,

Karen Ross, Secretary
California Department of Food and Agriculture

Enclosures

cc: Natalie Krout-Greenberg, Director
Inspection Services Division

Steve Patton, Branch Chief
Inspection Services Division

Shelley Phillips, Supervising Senior Environmental Scientist
Produce Safety Program

U.S. FOOD & DRUG
ADMINISTRATION

September 13, 2017

Steve Patton
Branch Chief
1220 N Street
Sacramento, CA 95814

Dear Mr. Patton:

On September 12, 2017, the Food and Drug Administration (FDA) announced a postponement of the implementation of routine inspections of farms subject to the Produce Safety Rule until spring 2019. The announcement also addressed the extension of the compliance date for agricultural water standards and described how FDA will work with stakeholders to modify agricultural water standards in the future.

In light of this announcement, we are modifying the approach outlined in the cooperative agreements so that routine inspections will begin in spring 2019. This will allow states and FDA an opportunity to focus on issuing guidance and training plans, along with conducting On-Farm Advisory (Readiness) Reviews (OFRRs) in 2018. "For-cause" inspections (such as those related to outbreak investigations) will still occur, as needed, and will not change in light of this announcement. The new routine inspection timeline is as follows:

- Large Farms
  - Compliance Date - 1/26/2018; Inspection Start Date – March - June 2019
- Small Farms
  - Compliance Date - 1/28/2019; Inspection Start Date – March - June 2020
- Very Small Farms
  - Compliance Date - 1/27/2020; Inspection Start Date – March - June 2021

We ask that all State Produce Implementation Cooperative Agreement Program (CAP) grantees adjust their inspection implementation timelines according to the above schedule and reassess their strategic plans and budgets to determine the impact of these decisions, if any. We encourage states to consider reprogramming resources planned for inspections in 2018 to conducting OFRRs.

FDA, working closely with our association partners, is scoping out all activities that can be performed in lieu of routine inspections in Year 2. We will also be finalizing CAP-related information and decisions necessary to implement inspections in 2019. We will share this information with you no later than November 1, 2017, so you will have time to revise your strategic plans and budgets, if necessary, and submit them, along with your mid-year progress reports, by December 1, 2017.

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While reassessing your program's strategic plan and budget please be mindful that all other planned activities under your existing cooperative agreement will continue including:

- Developing and continually updating your strategic plan for produce safety (continuation from Year 1)
    - Developing, documenting, and tracking performance measures
- Conducting a jurisdictional self-assessment (continuation from Year 1)
- Establishing and verifying a farm inventory (continuation from Year 1)
- Conducting legislative research and continuing any efforts to obtain regulatory authority (continuation from Year 1)
- Developing program and program infrastructure (continuation from Year 1 and/or new)
    - Developing and implementing a continuing education program to ensure regulatory jurisdiction personnel are trained
    - Establishing ties with FDA's Produce Safety Network and FDA's Technical Assistance Network to ensure that any questions or issues are raised and state/territory regulators receive necessary technical assistance
    - Researching, designing, and implementing a compliance program for applicable produce safety regulations at the jurisdictional level, which includes:
        - Continuing program development work, but adjusting for the new targeted start date; and
        - Delaying implementation of the inspection program and redirecting those resources to OFRRs and other education and outreach programs
    - Continuing communication and collaboration amongst CAP stakeholders
- Performing education and outreach (continuation from Year 1 and/or new)
    - Evaluating educational needs and implementing an educational system to provide for an informed farming community
    - Participating in and providing opportunities for OFRRs

The implementation of the Food Safety Modernization Act (FSMA) and the Produce Safety Rule has been and continues to be a top priority for FDA. As you know, states have a long history of effectively working with and understanding your farming communities. Successful implementation of the Produce Safety Rule cannot happen without the support of our state partners who are helping food producers and growers understand and achieve the new requirements.

FDA is committed to ensuring our regulatory partners and industry have the tools needed to implement the new standards. As we continue to work together with FSMA implementation, we recognize that achieving our shared food safety goals is a continuous effort from all of us.

Thanks for your commitment to integration and food safety. We look forward to our continued partnership.

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part 112, or the FSVP regulation are still required to make necessary disclosures. Subsequent entities in the distribution chain will continue to be subject to applicable requirements related to food adulteration in Federal and/or state and local laws and regulations, e.g., part 117, part 507, and the Retail Food Code.

## C. Enforcement Policy for Importation of Food Contact Substances Under the FSVP Regulation

The FSVP regulation requires food importers to develop, maintain, and follow an FSVP that provides adequate assurances that the foreign supplier uses processes and procedures that provide the same level of public health protection as those required under the preventive controls or produce safety provisions of FSMA (if applicable) and regulations implementing those provisions, as well as assurances that the imported food is not adulterated and that human food is not misbranded with respect to allergen labeling (21 CFR 1.502(a)). Among other things, the FSVP regulation (21 CFR 1.500-1.514) requires most food importers to do the following:

- Analyze the hazards for the foods they import (21 CFR 1.504);
- Evaluate the performance of their potential foreign suppliers and the risk posed by the foods to be imported (21 CFR 1.505); and
- Determine and conduct appropriate foreign supplier verification activities, such as onsite auditing of foreign suppliers, sampling and testing, and review of supplier food safety records (21 CFR 1.506).

The FSVP regulation applies (with certain exceptions) to the importation of food as defined in section 201(f) of the FD&C Act (see 21 CFR 1.500). Food contact substances are included in the definition of "food" for purposes of the FSVP regulation (21 CFR 1.500). However, for the reasons stated below, we intend to exercise enforcement discretion for importers of food contact substances with respect to the FSVP regulation.

A food contact substance is any substance that is intended for use as a component of materials used in manufacturing, packing, packaging, transporting, or holding food if such use of the substance is not intended to have any technical effect in such food (section 409(h)(6) of the FD&C Act (21 U.S.C. 348(h)(6)); 21 CFR 170.3(e)(3)). The term "food" is defined in section 201(f)(3) of the FD&C Act to include articles used as components of food. In the preamble to the FSVP final rule, we stated that the definition of "food" for purposes of FSVP includes food contact substances that are considered "food" in section 201(f) of the FD&C Act (80 FR 74225 at 74233). Therefore, the FSVP regulation applies to importers of food contact substances that meet the definition of "food" in section 201(f).

In the compliance date final rule, we extended the compliance date for the importation of food contact substances by 2 years so that we could consider how best to address concerns raised about the feasibility of importers of food contact substances meeting the FSVP requirements (81 FR 57784 at 57792-57793). As a result of this extension, the earliest that an importer would be required to comply with FSVP for the importation of food contact substances would be May 28, 2019.

- Subpart C of part 507 includes provisions for disclosure statements and written assurances that apply when a manufacturer/processor of food for animals identifies a hazard requiring a preventive control, does not control the identified hazard, and relies on an entity in its distribution chain to control the hazard (§§ 507.36(a)(2), (3), and (4), 507.36(c), 507.36(d), and 507.37). A manufacturer/processor that complies with these provisions of part 507 is not required to implement a preventive control for the identified hazard. The combination of these requirements was intended to provide assurance that the food will be processed to control the identified hazard before it reaches the consumer feeding the food to animals.
- Subpart F of part 507 specifies the elements to be included in the written assurances required by § 507.36(a)(2)(ii), (3)(ii), and (4)(ii). (See § 507.215(b).)

The FSVP regulation includes "customer provisions" that apply when an importer imports a food for which the hazards are controlled after importation (§ 1.507). As with the customer provisions in part 117 and part 507, the requirements in the customer provisions of the FSVP regulation were intended to provide assurance that the food will be processed to control the identified hazard before it reaches the humans or animals that would consume the food.

The produce safety regulation applies to "covered produce" as set forth in §§ 112.1 and 112.2. Produce that would otherwise be covered is eligible for an exemption from most of the requirements of the produce safety regulation if: (1) The produce receives commercial processing that adequately reduces the presence of microorganisms of public health significance (§ 112.2(b)(1)); and (2) certain other conditions are met, including requirements for disclosure statements and written assurances analogous to the requirements for disclosure statements and written assurances in the "customer provisions" required by part 117, part 507, and the FSVP regulation (§ 112.2(b)(2) through (4) and (6)).

FDA has received feedback from industry expressing concern that certain product distribution chains would require vastly more written assurances (and consequently resources to comply with the requirement) than anticipated by FDA during the rulemaking process (Ref. 1). For example, a manufacturing facility may sell food products subject to the customer provisions to a distributor, who may sell numerous items requiring assurances to multiple restaurants, cafeterias, delicatessens, and other distributors. It is estimated that this could result in hundreds or even thousands of written assurances needed by a single distributor (Ref. 1). After considering this feedback from industry, we stated our belief that the requirement for written assurance in the customer provisions of part 117 significantly exceeds the current practices of even the largest facilities; compliance by those facilities by September 19, 2016, may not be feasible; and it is appropriate to extend the compliance dates for 2 years for the written assurance requirements for part 117, part 507, the FSVP regulation, and the produce safety regulation while we considered the best approach to address feasibility concerns (81 FR 57784 at 57786).

FDA intends to initiate a rulemaking that takes into consideration the complex supply chain relationships and resource requirements. To provide sufficient time for us to pursue that rulemaking, we are exercising enforcement discretion with regard to the written assurance requirements of part 117, part 507, part 112, and the FSVP regulation until completion of that rulemaking process. In the meantime, entities with disclosure duties under part 117, part 507, squash, winter; sweet potatoes; and water chestnuts.

(2) Produce that is produced by an individual for personal consumption or produced for consumption on the farm or another farm under the same management; and

(3) Produce that is not a raw agricultural commodity.

(b) Produce is eligible for exemption from the requirements of this part (except as noted in paragraphs (b)(1), (2), and (3) of this section) under the following conditions:

(1) The produce receives commercial processing that adequately reduces the presence of microorganisms of public health significance. Examples of commercial processing that adequately reduces the presence of microorganisms of public health significance are processing in accordance with the requirements of part 113, 114, or 120 of this chapter, treating with a validated process to eliminate spore-forming microorganisms (such as processing to produce tomato paste or shelf-stable tomatoes), and processing such as refining, distilling, or otherwise manufacturing/processing produce into products such as sugar, oil, spirits, wine, beer or similar products; and

(2) You must disclose in documents accompanying the produce, in accordance with the practice of the trade, that the food is "not processed to adequately reduce the presence of microorganisms of public health significance;" and

(3) You must either:

(i) Annually obtain written assurance, subject to the requirements of paragraph (b)(6) of this section, from the customer that performs the commercial processing described in paragraph (b)(1) of this section that the customer has established and is following procedures (identified in the written assurance) that adequately reduce the presence of microorganisms of public health significance; or

(ii) Annually obtain written assurance, subject to the requirements of paragraph (b)(6) of this section, from your customer that an entity in the distribution chain subsequent to the customer will perform commercial processing described in paragraph (b)(1) of this section and that the customer:

(A) Will disclose in documents accompanying the food, in accordance with the practice of the trade, that the food is "not processed to adequately reduce the presence of microorganisms of public health significance"; and

(B) Will only sell to another entity that agrees, in writing, it will either:

(*1*) Follow procedures (identified in a written assurance) that adequately reduce the presence of microorganisms of public health significance; or

(*2*) Obtain a similar written assurance from its customer that the produce will receive commercial processing described in paragraph (b)(1) of this section, and that there will be disclosure in documents accompanying the food, in accordance with the practice of the trade, that the food is "not processed to adequately reduce the presence of microorganisms of public health significance"; and

(4) You must establish and maintain documentation of your compliance with applicable requirements in paragraphs (b)(2) and (3) in accordance with the requirements of subpart O of this part, including:

(i) Documents containing disclosures required under paragraph (b)(2) of this section; and

(ii) Annual written assurances obtained from customers required under paragraph (b)(3) of this section; and

(5) The requirements of this subpart and subpart Q of this part apply to such produce; and

(6) An entity that provides a written assurance under §112.2(b)(3)(i) or (ii) must act consistently with the assurance and document its actions taken to satisfy the written assurance.

### § 112.3 What definitions apply to this part?

(a) The definitions and interpretations of terms in section 201 of the Federal Food, Drug, and Cosmetic Act apply to such terms when used in this part.

(b) For the purpose of this part, the following definitions of very small business and small business also apply:

(1) *Very small business*. For the purpose of this part, your farm is a very small business if it is subject to any of the requirements of this part and, on a

# FSMA Produce Safety Rule

## What Produce Associations Need to Know

- California Department of Food Agriculture (CDFA) is launching the California Produce Safety Program, which will include educational information designed to assist California produce farms in understanding the requirements of the FDA's Produce Safety Rule and how to comply with this new regulation.

- Beginning January 26, 2018, California produce farms designated as "large" (those with annual sales greater than $500,000) are expected to comply with the Produce Safety Rule. Smaller farms will be phased in over the next few years.

- The Produce Safety Rule is mandatory throughout the United States beginning January 26, 2018. Any produce farm found to be out of compliance may be subject to regulatory actions.

- In 2018, the Produce Safety Program will be doing everything possible to inform and educate California produce farmers about the requirements of the Produce Safety Rule.

## Who Must Follow the Produce Safety Rule?

- California farms producing fruits, nuts and vegetables must comply with this new rule.

- Multiple rules exist within the federal Food Safety Modernization Act (FSMA). The Produce Safety Program deals specifically with the Produce Safety Rule. Information about other FSMA Rules is available here.

- The exact rule an operation falls under will vary depending upon the type of activities performed. To determine if an operation falls under the Produce Safety Rule, please use this flow chart provided by The National Sustainable Agriculture Coalition.

## CDFA Produce Safety Program Website Coming Soon

**www.cdfa.ca.gov/producesafety/**

CDFA is currently developing a new Produce Safety Program website. This will serve as the go to place for individuals looking for PSR information.

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## Who is Exempt from the Produce Safety Rule?

- A list of exemptions from the Produce Safety Rule can be found here. Exemptions generally include the following:

- Thirty commodities have been identified by the FDA as exempt from the Produce Safety Rule because they are rarely consumed raw. Farms exclusively producing these commodities are not covered by the Produce Safety Rule. (Examples of exempt commodities include: dried kidney beans, potatoes and pumpkins.)

- Farms that grow produce only for personal consumption or very limited distribution may also be exempt from the law.

- Some farms may qualify for an exemption from the Produce Safety Rule if their sales are below certain levels or if they grow produce that is processed in a way that would kill pathogens. Farms falling in these categories will be required to verify their exemption status.

- If your organization represents commodities that may be eligible for a qualified exemption because the finished product is processed in a way that kills pathogens, CDFA strongly urges you to seek guidance from FDA regarding documentation requirements to verify this exemption.

- CDFA is also urging associations to work with industry members to ensure procedures for documentation for qualified exemptions required of both farmers and processers are well understood and communicated.

# Education and Training

- FDA has determined that official Produce Safety Rule on farm inspections will begin in 2019. The Produce Safety Program will spend 2018 working to make sure California produce farmers understand the requirements of the Produce Safety Rule.

- An informational website providing detailed information on the Produce Safety Program will be available soon and CDFA will be conducting other outreach efforts to educate California produce farms about this new rule and how to comply.

- One of the first steps toward Produce Safety Rule compliance is for every produce farm to have an individual employed who has completed an FDA-recognized Produce Safety Rule Grower Training Course. The training need only be taken once and the certificate of completion belongs to the individual. Available courses are posted on the Produce Safety Alliance website here.

- CDFA has also contracted with outside organizations to provide subsidized Grower Training that meets Produce Safety Rule requirements. These courses are offered at a reduced rate and are being conducted throughout the state in both English and Spanish. A list of dates and locations of these courses is provided with this packet.

- In addition to the required Produce Safety Rule Grower Training, all produce farms must show documentation of ongoing food safety training of farm and contracted employees as part of the required practices under the Produce Safety Rule.

- Any information or assistance your association can provide to ensure farmers are meeting Produce Safety Rule training requirements is greatly appreciated.

- In preparation for official Produce Safety Rule inspections in 2019, CDFA's Produce Safety Program will be offering a series of On-Farm Readiness Reviews (OFRR). These are designed to give produce farmers a better understanding of what they can expect from a Produce Safety Program routine inspection. Information on how to schedule an OFFR will be available very soon.

# Information for the Public and Other Stakeholders

- Please note that California Produce Safety Program inspections are a means of verifying compliance and enforcement of the Produce Safety Rule. They are not meant to replace existing quality assurance activities that may be requested of farmers or handlers by their customers.

- Suggested messaging for use in talking about the Produce Safety Program with trade and consumers is included in this packet.

- CDFA urges you to share information contained in this packet with your membership.

# Implementation of Required Food Safety Practices

- Produce farms with sales greater than $500,000 per year are expected to implement Produce Safety Rule practices beginning January 26, 2018. The full Produce Safety Rule requirements are available on the FDA website here.

- If your association has commodity specific guidelines that are aligned with the Produce Safety Rule, we encourage you to share these with your membership.

- We also urge you to advise your membership that private audit firms should conduct audits that are aligned with the Produce Safety Rule so that farmers are well prepared for Produce Safety Program inspections when they begin taking place in 2019.

# Produce Safety Program Inspections

- CDFA has created a new unit as part of its Inspection Services Division specifically to conduct Produce Safety Rule inspections. This unit is known as the Produce Safety Program.

- Produce Safety Rule inspections will be done on behalf of the U.S. FDA. As such, Produce Safety Program inspectors are credentialed by the FDA and have specific education and training.

- As with all other programs within the CDFA's Inspection Services Division, Produce Safety Program inspectors are part of a public agency mandated to protect the food supply. Inspectors are: accountable to the public, legislature and the industry; financially independent and unbiased; consistent and uniform; and are required to report potential public health threats to the California Department of Public Health.

- CDFA is working with an existing database of California farms acquired from other agencies and organizations to identify California produce farms that are likely subject to this new rule. Farms from this list will be selected for routine inspection by the Produce Safety Program on a random basis following verification of the farm's status.

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# Suggested Messaging for Retail and Foodservice Produce Buyers

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## About the Produce Safety Rule

- Beginning January 26, 2018, the Produce Safety Rule under the new Food Safety Modernization Act will become law on produce farms throughout the U.S.

- All California farms producing fruits, nuts and vegetables must comply with this new law. Some exceptions apply. Your supplier can provide verification if they are exempt from the Produce Safety Rule.

- The law will be phased in according to farm size over the next few years beginning in 2018 with large farms, defined as those with annual sales of $500,000 or more.

- To implement this new law across the nation, the U.S. FDA is working with State Departments of Agriculture to conduct inspections that will verify produce farms are in compliance with the Produce Safety Rule.

- The U.S. FDA has determined that Produce Safety Rule on-farm inspections will begin in 2019.

## Implementation in California

- It is estimated some 20,000 produce farms in California are subject to the Produce Safety Rule.

- The California Department of Food and Agriculture has created a new unit as part of its Inspection Services Division specifically to conduct inspections that will verify compliance with the Produce Safety Rule. This unit is known as the Produce Safety Program.

- The goal of CDFA's Produce Safety Program is to assist and verify that California produce farms are following FDA's Produce Safety Rule.

- This is a big job and it will take time to fully implement. CDFA's goal is for Produce Safety Rule requirements to become ingrained in the culture of California produce farming so that our state is growing the safest produce possible.

- The California Produce Safety Program's role is to first educate California produce farmers on the requirements of the Produce Safety Rule and then regulate farms to ensure they are following this new rule.

## About the Produce Safety Program Inspections

- California Produce Safety Program inspections are a means of verifying compliance and enforcement of the Produce Safety Rule. They are not meant to replace existing quality assurance activities provided by farmers or handlers.

- Beginning in 2019, California produce farms will be selected for inspection by the Produce Safety Program on a random basis following verification of the farm's status.

- Unlike audit based certification programs, farms may not request an inspection, but will instead be selected by the Produce Safety Program.

# Suggested Messaging for Consumers

cdfa PRODUCE SAFETY PROGRAM

## About New Food Safety Regulations for Produce

- Beginning on January 26, 2018 fruit, vegetable and nut farms in California and throughout the U.S. will be required to follow specific food safety practices under a new federal regulation known as the Produce Safety Rule.
- The U.S. Food and Drug Administration (FDA) has been charged with oversight of this new rule and it is being implemented in California by the California Department of Food and Agriculture (CDFA).
- Food safety practices required on farms are similar to what is required of restaurants or to precautions you might take in your own kitchen. The practices are designed to ensure produce is properly handled by workers who are trained to use good hygiene; to make sure farm equipment is sanitary, to ensure soils where produce is grown are safe and, that measures are in place to prevent contamination of produce by wildlife or nearby domesticated animals. Additionally, farmers are required to keep written records to document their farming practices.
- Many produce farms have been implementing these kinds of food safety practices on their farms for years.

## What Consumers Can Expect from Produce Grown in California

- Routine on-farm Inspections to verify farmers are following new food safety regulation will be conducted through an inspection unit created by the California Department of Food and Agriculture called the Produce Safety Program.
- It's estimated that 20,000 farms in California are subject to the Produce Safety Rule. It is the goal of CDFA that requirements of this new food safety rule become ingrained in the culture of California produce farming so that our state is growing the safest produce possible.
- Over the next year, the role of the California Department of Food and Agriculture's Produce Safety Program will be to educate California produce farmers about the requirements of the Produce Safety Rule.
- Beginning in 2019, CDFA's Produce Safety Program inspectors will conduct random, routine inspections of produce farms to ensure they are following the new law.
- Inspectors in California are credentialed by the FDA and have specialized education and training. The inspectors are part of a government agency charged with protecting the food supply. They provide independent, unbiased, consistent inspections of California produce farms.
- Most grocery stores and restaurants already require farmers to follow food safety practices on their farms. In addition, many organizations conduct research and provide food safety guidelines that produce farmers have been following for years.
- Requirements for produce safety on farms is now the law. Farmers found to be out of compliance with these new requirements may face economic, regulatory and legal consequences.

## Introduction

The walk around questions (WAQ) are intended to help assessor(s) solicit information from the grower. It is not intended to cover all aspects of the Produce Rule, but what is considered the most important portions. The WAQ is to be used with the OFRR Resource Manual. The assessor(s) should have a good understanding of the produce rule and the manual before doing any readiness reviews.

The assessor should first talk to the grower about what portions of the Produce Rule apply to them. Use the OFRR Decision Tree which is located at Tab 4 in the manual. This will allow you and the grower to determine which parts to use for the walk through. Each Tab in the manual from 4-15 covers a different section of the Rule with a corresponding WAQ. The WAQ documents are setup as a series of questions. At the start of most questions is a section number in brackets i.e. [112.51] which refers directly to the Rule under that tab in the manual. If a written document is required, the section number will be followed by a capital D in parenthesis i.e. (D).

At the end of the walk through the assessor(s) should meet with the grower to review what was observed and make suggestions for improvement. The goal is not to point out everything that the grower may need to change, but the most important changes needed.

## Walk Around Questions (WAQ)

## Health and Hygiene (Tab 4)

Potential locations – immediately upon arrival if asked to sign an acknowledgment of food safety practices document, employee break area, hand wash station, restroom

[112.31]; How do you prevent ill or persons you suspect of being sick from coming into contact with produce and food contact surfaces?

[112.32]; What sort of hygiene expectations do you have for all your employees? Do you have glove, jewelry, or other similar policies?

[112.33]; What are your visitor policies or procedures related to health and hygiene.

## Walk Around Questions (WAQ)

## Preharvest Biological Soil Amendments of Animal Origin (5)

Potential locations – compost pile, compost storage, composting area

[112.52(a), 112.52(b)]; Does your farm use any soil amendments of animal origin, including agricultural tea?

[112.52]; If yes, how is it stored and handled prior to application?

[112.51(b)(5), 112.54] (D); Do you test the water for the tea and if so what for?

Do you spike the tea with anything (nutrients or other additives)?

[112.51, 112.54]; What type of soil amendments do you use? (Note to assessors: probe deeper regarding use of human waste, sewage sludge biosolids, manure, compost, bone meal, feather meal, fish emulsion, table waste, pre-consumer vegetative waste, etc.)

[112.52] When do you apply your amendments?

[112.56]; Do they contact the harvestable portion of the crop during or after application?

[112.56(a)(1)(i)]; How long do you wait before harvesting after application?

[112.53] (D); Does your farm use any human waste or sewage sludge biosolids?

[112.60(b)(1), 112.60(b)(2)] (D); Do you produce your own compost or purchase it pre-treated?

[112.60(b)(1)] (D); If you buy treated compost amendments, do you maintain a certificate or document from that supplier the microbial quality of the product at least annually?

[112.54, 112.55]; Is the process used to treat it scientifically valid (Ex.'s physical process (ex. thermal), chemical process (ex. High alkaline pH), biological process (Ex. composting) or a combination of these, and validated to show no detectable *Listeria monocytogenes*, *Salmonella* species and fecal coliforms or *E. coli* O157:H7 for purchased compost?

If you produce your own compost, where do you produce it and how is it stored?

[112.60(b)(1)(i)], [112.60(b)(1)(iii)], (D); Do you have a record of the process used to treat the amendment?

[112.60(b)(1)(ii)] (D); Do you have a record of the handling and storage of the amendment?

## Walk Around Questions (WAQ)

## Preharvest and Harvest Wild and Domestic Animals (Tab 6)

Potential locations – working animals, animal deterrents, walking field perimeter

[112.81]; Does your farm operation grow, pack or hold produce in an outdoor area or partially enclosed building? (May be obvious upon visiting farm operation)

[112.83]; Does your farm use grazing animals, working animals, or have animals entering production areas during the season?

[112.83(a)]; What steps do you take if you suspect that grazing animals, working animals, or animal intrusion will contaminate covered produce?

[112.83(b)]; How do you assess potential contamination during the season?
[112.112]; If contamination is found, how do you evaluate whether produce can be harvested?

* [112.22(b)(1); 112.30(b)]; What type of training do workers receive on dealing with contaminated produce at harvest?

## Walk Around Questions (WAQ)

## Preharvest Worker Training (Tab 7)

Potential locations – employee break area, hand wash station, restroom

*[112.21(a), 112.22(a)(1); When do you train your workers on hygiene? What do you cover? How often do you retrain? How do you handle new employees during the season?

*[112.21(b)]; What type of training to you or the supervisors of the workers receive?

*[112.22(b), 122.22(b)(3)]; Do you give different types of training for your field and packinghouse crews? If so what?

*[112.30] (D); Do you keep records of your trainings?

*[112.129]; What type of toilet facilities and handwashing stations do you provide?

*[112.130]; What supplies are included with the toilets and handwashing facilities

*[112.129(b)(2)]; How are they serviced?

*[112.129(b)(1), 112.131(c)]; What do you do if a portable toilet leaks, tips, or spills?

*[112.129(a)]; Where are toilets in relation to the work being done and how many do you have?

## Walk Around Questions (WAQ)

## Preharvest Sanitation (Tab 8)

Potential locations – production equipment, chemical storage, walking the field

[112.111]; Do you grow crops that are covered and not covered under the produce rule? If so, do you clean any shared equipment before using on covered produce?

[112.112]; Do you do a preharvest inspection of the growing area? What do you look for? What are your corrective actions if you find a problem? How do you ensure contaminated produce will not be harvested?

[112.123] (D); Do you inspect and maintain equipment, and when necessary clean and sanitize equipment used in the field before harvest? (Distinguish between cleaning and sanitizing). How do you do it? What sort of sanitizer do you use? How often?

112.140]; Do you keep records of equipment sanitation?

[112.132] How do you dispose of waste in the field to prevent contamination of produce and ag water?

## Walk Around Questions (WAQ)

## Preharvest Water (Tab 9)

Potential locations – water source (well or surface), water treatment system, distribution system

How do you use water before the harvest of crops on your farm (i.e., is it considered *agricultural water*)?

[112.42(a)(1)] (D); What are the sources of water used throughout the season [Municipal, Groundwater (i.e., wells), Surface Water (lakes, ditches, rivers or streams), How many?]?

Think about all the water used for irrigation, crop protection, frost protection, and dust abatement. How do the sources change during different times of year or with how you use the water?

[112.42(a)] (D); Do you inspect your water system? If so how often? What things do you look for in the inspection? (Ask the grower to walk through a typical inspection with you.)

[112.42(a)(4)] (D); What are the specific activities near the source or through the conveyances that impact the quality of these water sources (On this farm, from adjacent land)? How likely will these activities contaminate the water source?

[112.42(c)]; How do you protect your water sources? (physical access, backflow prevention)

[112.46] (D) How do you assess water quality for preharvest uses? Testing? How frequently and when? What test(s) [target organism, testing method] are you using? Do you know what your water unit testing is?

[112.47(b)]; How do you take your water samples?

Note: Exact requirements listed below are under review by FDA and may change. Also, water requirements do not go into effect for four years after implementation dates based on produce sales.

Municipal Source (a record of the annual testing from the municipality)
Ground water sources (4 tests total with 1 per year, per source)
Surface water sources (20 tests total with 5 per year, per source)

[112.44(b)] (D); Are you calculating a Geometric mean and STV?

[112.44(b)] (D); Does your water meet the *E. coli* criteria established in the PSR? (<126 CFU GM & <410 CFU)?

[112.45]; If your water happened to exceed the *E. coli* criteria, what corrective measures would you use to lower the risk?

[112.45(a)(1)] (D); If it did exceed the criteria, did you reinspect the system to look for problems before performing a corrective action?

* [112.45(b)(1)(i)(A)] (D); Are you applying a preharvest interval? How many days?

(D) Does your crop go to commercial processing? Is your buyer aware that risky produce (ie.high micro load water application preharvest) needs to be handled differently?

[112.45(b)(1)(ii)] (D); Postharvest treatment or storage? Do you have a validation to show its efficacy?
[112.45(b)(2)] (D); Re-inspecting the water system?
* [112.45(a)(2)] (D); Do you treat the water? If so, how?

[112.45 (b)] (D); Have you had to take any Corrective Actions this season?

[112.12 (a)] (D); Do you use an alternative to a requirement?
[112.49 (a)] (D); Alternative microbial Indicator? Do you have scientific data to support it?
[112.49 (b)] (D); Alternative preharvest die-off? Do you have scientific data to support it?
[112.49 (c)] (D); Alternative minimum sample number in initial survey? Do you have scientific data to support it?
[112.49 (d)] (D); Alternative minimum sample number in annual survey? Do you have scientific data to support it?

## Walk Around Questions (WAQ)

## Harvest Worker Training (Tab 10)

Potential locations – employee break area, hand wash station, restroom, watching harvest

[112.112]; Do you inspect fields at harvest for signs of animal feces? What do you if feces in found on or around the produce?

[112.113]; How do you protect the produce from becoming contaminated during harvest?

[122.22(b)(2), 122.22(b)(3); What does a worker do if he/she fines containers that were not properly cleaned when harvesting?

[112.129]; What type of toilet facilities and handwashing stations do you provide?

[112.129]; How close are the toilet facilities located to the field during harvest?

[112.129(b)(2)]; How are they serviced?

[112.130]; What supplies are included with the toilets and handwashing facilities

[112.129(b)(1), 112.131(c)]; What do you do if a portable toilet leaks, tips, or spills?

[112.129(c); If you are growing in a greenhouse where are the toilets and handwashing stations located?

[112.21(a), 112.22(a)(1); When do you train your workers on hygiene? What do you cover? How often do you retrain? How do you handle new employees during the season?

[112.21(b)]; What type of training to you or the supervisors of the workers receive?

[112.21(c)]; How do you train workers that may not read or write or understand English?

[112.22(b), 122.22(b)(3)]; Do you give different types of training for your field and packinghouse crews? If so what?

[112.30] (D); Do you keep records of your trainings?

[112.22(a)(2); How do you inform visitors (including u-pick) as to the health and safety issues around the operation?

## Walk Around Questions (WAQ)

## Harvest Sanitation (Tab 11)

Potential locations – watching harvest, looking at harvest equipment, looking at where harvest equipment is stored or cleaned

[112.22(b)] (D); What type of training do you give to the harvest crew?

[112.22(b)(1)] (D); What instructions do you give to the harvest crew related to dropped produce or produce which may be contaminated with manure or other animal feces?

[112.111]; Do you grow crops that are covered and not covered under the produce rule? If so, do you handle and/or store the crops together or use any shared equipment?

[112.112]; Do you do a preharvest inspection of the growing area? What do you look for? What are your corrective actions if you find a problem? How do you ensure contaminated produce will not be harvested?

[112.113]; How do you handle harvested produce to prevent contamination?

[112.114]; How do you ensure dropped produce is not distributed?

[112.116]; Do you reuse packing / harvest containers? If so, how are they cleaned and sanitized?

[112.123] (D); How frequently do you inspect and maintain equipment, and when necessary clean and sanitize equipment used in the field before harvest? (Distinguish between cleaning and sanitizing). How do you do it? What sort of sanitizer do you use? How often?
112.140]; Do you keep records of equipment sanitation?

[112.125]; How do you ensure vehicles used to transport produce are cleanable (look for carpet, absorbent material, etc.), clean and/or sanitary?
[112.132] How do you dispose of waste in the field to prevent contamination of produce and ag water?

## Walk Around Questions (WAQ)

## Harvest Water (Tab 12)

Potential locations – water source, point of water use, during harvest

How do you use water (including ice) during the harvest of crops on your farm?
**[112.42(a)(1)] (D); What are your sources of water used at harvest?

Think about all the water used for equipment and direct food contact surface cleaning, hand wash water, for produce quality (freshening greens) and hydrocooling. How do the sources change during different times of year or with how you use the water?

**[112.42(a)] (D); Do you inspect your water system? If so how often? What things do you look for in the inspection? (Ask the grower to walk through a typical inspection with you.)

**[112.42(a)(4)] (D); What are the specific activities near the source or through the conveyances that impact the quality of these water sources (On this farm, from adjacent land)? How likely will these activities contaminate the water source?

**[112.42(c)]; How do you protect your water sources? (cross-connections, backflow prevention)

**[112.46] (D); How do you assess water quality for harvest uses? Testing? How frequently and when? What test(s) [target organism, testing method] are you using? Do you know what your water unit testing is? How do you take your water samples?

**[112.43] (D); Do you treat this water? If so, how?

**[112.45]; What do you do if a water test comes back higher than expected (a positive generic *E. coli* test)? How would you correct this on your farm?

[112.48(a)] Do you re-use or recirculate water? If so, how do you monitor recirculating water? How do you determine when it's time to change recirculated water?

**[112.43] (D); Do you use an antimicrobial (sanitizer, uV)? How do you use them? How do you monitor their effectiveness? How frequently do you monitor it?
(Depending on your sanitizer) How do you monitor the pH of this water?

[112.48(b)]; Are you familiar with water turbidity? How do you gauge/measure this?
[112.48(c)]; Based on what you harvest, is the temperature of the water a concern? How do you address it?

*[112.50(a)] (D); What documents do you keep related to your water sources, antimicrobial use, and testing?

## Walk Around Questions (WAQ)

## Postharvest Worker Training (Tab 13)

Potential locations – employee break area, hand wash station, restroom, watching packing

[112.129(a)]; Approximately how many workers do you have in the packinghouse?

[112.129(b)(1)]; Are there toilet facilities and handwashing stations available for the workers during produce packing and where are they located?
Who services the facilities and how frequently?

[122.22(b)(2), 122.22(b)(3); What does a worker do if he/she fines containers that were not properly cleaned after harvest?

[112.129]; What type of toilet facilities and handwashing stations do you provide?

[112.129]; How close are the toilet facilities located to the packing area?
[112.129(b)(2)]; How are they serviced?

[112.130]; What supplies are included with the toilets and handwashing facilities

[112.129(b)(1), 112.131(c)]; What do you do if a portable toilet leaks, tips, or spills?

[112.129(c); If you are growing in a greenhouse where are the toilets and handwashing stations located?

[112.21(a), 112.22(a)(1); When do you train your workers on hygiene? What do you cover? How often do you retrain? How do you handle new employees during the season?

[112.21(b)]; What type of training to you or the supervisors of the workers receive?

[112.21(c)]; How do you train workers that may not read or write or understand English?

[112.22(b), 122.22(b)(3)]; Do you give different types of training for your packinghouse crew? If so what?

[112.30] (D); Do you keep records of your trainings?

[112.22(a)(2); How do you inform visitors as to the health and safety issues around the operation and do you provide them with toilet and handwashing facilities?

## Walk Around Questions (WAQ)

## Postharvest Sanitation (Tab 14)

Potential locations –observe packing, observe cleaning/sanitation at packinghouse, chemical storage area, cold rooms and other storage areas

[112.111]; Do you harvest and handle both covered and non-covered produce? If so, do you separate covered and non-covered produce? If so, please describe separation (physical, time, handling, cleaning).

[112.113]; How do you handle produce that contacts the ground, packinghouse floor, or other non-food contact surface?

[112.123] (D); Do you clean and/or sanitize equipment?

- [112.123(d)(1)]; How do you clean equipment? Do you sanitize cleaned equipment? If so, how?
- [112.140]; Do you keep records? If so, what records?

[112.116]; How do you ensure your packaging materials are clean and sanitary?

- [112.116(a)]; How do you handle damaged or cracked containers?
- [112.115]; Does packaging allow for air flow?

[112.124]; Are you using any monitoring equipment i.e., temperature recorders, pH meters, etc.? If so, do you check their accuracy and how often?

[112.125]; How do you ensure vehicles used to transport produce are cleanable (look for carpet, absorbent material, etc.), clean and/or sanitary?

[112.126]; Are building drains, walls, ceilings and floors checked for leaks or other sources of contamination? How often are they cleaned? Are buildings adequate in size and construction (including adequate partitions and drainage)

- [112.126(a)(2)]; Is there standing water? If so, how is it addressed?
- [112.133]; Is plumbing sufficient?

[112.128]; Do you have a pest control program in place? If so, describe.

[112.127]; Are domestic animals allowed in the packinghouse?

[112.131]; What type of sewage system (septic, municipal, etc.) do you have for the packinghouse?

[112.132]; How often do you remove culled produce and trash from the packing area?

## Walk Around Questions (WAQ)

## Postharvest Water (Tab 15)

Potential locations – water source (well, connection to municipal), point of water use if during packing (hydrocooler, flume, dump tank, spray bar), sanitation

**[112.42(a)(1)] (D); What are your sources of water used during postharvest operations?
(Think about all the water used for equipment and direct food contact surface cleaning, hand wash water, dump tanks, ice making, fluming and hydrocooling.)

**[112.42(a)] (D); Do you inspect your water system? If so how often? What things do you look for in the inspection? (Ask the grower to walk through a typical inspection with you.)

**[112.42(a)(4)] (D); What are the specific activities near the source or through the conveyances that impact the quality of these water sources (On this farm, from adjacent land)? How likely will these activities contaminate the water source?

**[112.42(c)]; How do you protect your water sources (cross-connections, backflow prevention)?

**[112.46] (D); How do you assess water quality for postharvest uses? Testing? How frequently and when? What test(s) [target organism, testing method] are you using? Do you know what your water unit testing is? How do you take your water samples? Are you familiar with the Microbial Water Quality standards required for postharvest water?

[112.48(a)]; Do you re-use or recirculate water? If so, please describe.
How do you determine when it's time to change recirculated water?

**[112.43] (D); Do you use an antimicrobial (sanitizer, uV)? How do you use them? How do you monitor their effectiveness? How frequently do you monitor it?
(Depending on your sanitizer) Do you monitor the pH of this water?

[112.48(b)]; Are you familiar with water turbidity? How do you gauge/measure this?
[112.48(c)]; Based on what you harvest, is the temperature of the water a concern? How do you address it?

**[112.45] (D); What do you do if a water test comes back higher than expected (a positive generic *E. coli* test)? How would you correct this in your packinghouse?

*112.50(a) (D); What documents do you keep related to you water sources, antimicrobial use, and testing?

# CALIFORNIA APPLE EXPORT MARKETS

# WORLD APPLE REVIEW

The publication of the World Apple Review was released two decades ago by Dr. Desmond O'Rourke to provide the apple industry with an insight into issues occurring across the global market. The report includes summaries of both current and future issues within the industry. The 2018 edition of The World Apple Review, called *Drive for Quality - An Imperative for Apple Industry Prosperity*, has one dominant theme which identifies the key changes that are affecting our industry. Specifically, the review outlines changes that may affect areas such as production, trade, processing, consumption, marketing, pricing, and profitability in old and new apple varieties.

Other topics that this year's World Apple Review covers include the following and more:

- Can the period of recent prosperity be sustained?
- Demand for non-traditional fruits surging;
- More apples becoming available for export;
- Challenges penetrating markets in Middle East, Southeast Asia, South America;
- Apple demand responds slowly to income increases, strongly to price increases;
- How inflation and exchange rates are affecting global competition;
- Organics still winning the public relations battle over conventional fruit;
- Technology now an integral part of competition in fresh apples; and
- Labor anxiety is still pervasive. How close is automation as a solution?

These annual reviews have been beneficial in providing readers with an early insight and the knowledge to proactively address these issues as they arise in their businesses. Read more about the World Apple Review at www.e-belrose.com.

# CALIFORNIA APPLE EXPORT AND DOMESTIC MARKET OVERVIEW

The California Apple Commission has culminated the final export numbers for the 2018/2019 season. California exported a total of 107,564 boxes. Although exports were up this year, California has historically relied less on apple exports over the past several years for a number of reasons. First, the domestic pricing and early availability of California apples has priced out most foreign buyers. Further, the main varieties produced in California are better suited for the domestic market rather than the international market. Additionally, the international apple market has become highly competitive. For example, China has been flooding South East Asia with less expensive apples thus squeezing California out of the market. Finally, international trade agreements have created a difficult landscape with the inception of retaliatory tariffs from many countries across the globe. Unfortunately, many of these retaliatory tariff lists contain apples. Despite the industry's challenges, California is still heavily focused on maintaining a presence and supportive role in the international apple arena. The Commission believes that with the assistance of the U.S. Apple Export Council (USAEC), the entire U.S. apple industry can remain competitive in key international markets, thus relieving pressure on the domestic market.

California is still one of the largest exporters of apples in the United States and actively receives Market Access Program (MAP) dollars through the Foreign Agricultural Service (FAS) in order to maintain crucial export markets. Last season, the Commission, in conjunction with the U.S. Apple Export Council, received $898,685 for 2018/2019 MAP funding. Additionally, a new funding program, the Agricultural Trade Promotion (ATP) program, was announced by FAS in late 2018 as part of their efforts to provide support in order to offset recent tariffs on U.S. agricultural products. The USAEC applied for ATP program funds and received $196,515 for 2018-2019.

California receives numerous benefits from the MAP and ATP funding allocation since the state is considered one of the largest exporters on the Council, and has demonstrated a significant level of participation in nearly every export program. Below is a list of the top five countries that California shipped to during the 2018/2019 season. Additionally, the following pages feature: an overview of specific markets that are important to California; information on markets that receive Market Access Program (MAP), Technical Assistance for Specialty Crops (TASC), Emerging Market Program (EMP), or Agricultural Trade Promotion Program (ATP) funding; and all statistical apple shipping and destination information.

**Top Countries**

| | |
|---|---|
| 1) Canada | (68,566) |
| 2) Mexico | (29,681) |
| 3) Taiwan | (5,468) |
| 4) Columbia | (2,009) |
| 5) El Salvador | (1,840) |

**Top U.S. States**

| | |
|---|---|
| 1) California | (770,122) |
| 2) Texas | (142,131) |
| 3) Nevada | (87,539) |
| 4) Georgia | (31,571) |
| 5) Ohio | (28,302) |

# FOREIGN AGRICULTURAL SERVICE

The Foreign Agricultural Service (FAS) helps expand and maintain foreign markets for U.S. agricultural products by removing trade barriers and enforcing U.S. rights under existing trade agreements. 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 with the cooperators, such as U.S. Apple Export Council, to help U.S. 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), Emerging Market Programs (EMP), and the limited-time Agricultural Trade Promotion (ATP) Program. Each of these programs keeps U.S. products more competitive and counters the subsidized foreign competition seen in many international markets.

New for 2018, the USDA Foreign Agricultural Service announced $12 billion of immediate funding available to assist farmers impacted by recent tariff retaliations. The Agricultural Trade Promotion Program (ATP) accounts for $200 million in funding to develop foreign markets for U.S. agriculture. The ATP program will help U.S. agricultural exporters develop new markets and will help mitigate the adverse effects of other countries tariff and non-tariff barriers. The ATP provides cost-share assistance to eligible U.S. organizations for activities such as consumer advertising, public relations, point-of-sale demonstrations, participation in trade fairs and exhibits, market research, and technical assistance. The ATP program is available to all sectors of U.S. agriculture, mainly through partnerships with non-profit national and regional organizations. FAS administers the ATP under the authority of the Commodity Credit Corporation Charter Act.

In May of 2019, the U.S. Department of Agriculture announced a second round of trade mitigation funding, including additional ATP funds. Specifically, President Trump has authorized the USDA to provide an additional $16 billion in overall program funding. No new applications were necessary to apply for funds, rather they will be applied to applications submitted last fall. Funds have been expected to be disbursed for use in the 2019/2020 fiscal year.

Currently, the California Apple Commission, through partnership with the U.S. Apple Export Council, received a share of $898,685 in MAP funds for the 2018-2019 season. This funding allocation covered nine export markets, in which California participated in four of the markets. These dollars funded programs such as the Mexico inspection program, import and retail trade servicing within the export markets, consumer communication, trade missions, education, and market research. Also for the 2018-2019 season, the USAEC received a total of $202,000 in ATP funds for use in Latin America and the Middle East. This bring the total FAS funding for the USAEC to $1,100,685 for the 2018-2019 season.

FOREIGN AGRICULTURAL SERVICE
USDA

# U.S.-MEXICO-CANADA AGREEMENT

The new free trade agreement, which will replace NAFTA, is mostly focused on aspects of trade that affects the automotive industry. In terms of agriculture, it focuses mostly on the trade of dairy products from the U.S. to Canada, but it is shown to be in favor of the U.S. and has been estimated to provide about $70 million value to the U.S. dairy industry. With regard to other commodities, including apples, some additional factors that benefit all three countries include: Added modern language to enhance information exchange and cooperation in relation to Ag. biotechnology trade-issues; science-based sanitary and phytosanitary (SPS) measures will be used to facilitate trade; an agreement on grading standards and services; and a commitment from the U.S., Mexico, and Canada to provide notification of any issues with SPS inspection issues within five days, rather than seven days as the Trans-Pacific-Partnership called for.

On November 30, 2018, during the G-20 Summit, President Trump, Canadian Prime Minister Justin Trudeau, and former Mexican President Enrique Peña Nieto officially signed the USMCA. As of June 10, 2019, President Trump announced that tariffs on all goods exported to the U.S. from Mexico will be subject to a 5% tariff, that will reportedly increase to 25%, until the desired level of border security and elimination of illegal immigration is achieved. Thankfully, Mexico agreed to increase enforcement efforts regarding border security, and the U.S. responded by lifting the originally planned tariffs. Shortly after, Mexico's government officially became the first country to ratify the USMCA. The Commission is hopeful that the passage of this agreement by Mexico will eliminate the possibility of future tariff implementation from both the U.S. and Mexico.

Although the USMCA has been signed by the three leaders and ratified by Mexico, this agreement still needs to make its way through Congress for approval. Both Republican and Democrat members of Congress have their issues with the USMCA; however, the Trump administration's top trade official and current U.S. Trade Representative, Robert Lighthizer, has increased his outreach with Democrats on Capitol Hill in recent months. At this point, it seems that both sides of the aisle seemed hopeful that the administration and House Democrats could reach some sort of resolution to get the USMCA through Congress with bipartisan support. It has been rumored that the agreement is expected to be sent to Congress for a vote after September 1, 2019. The Commission will continue to provide timely updates to the industry on any progress made regarding the passage of the USMCA.

Shown left to right: Mexican President Enrique Pena Nieto, U.S. President Donald Trump and Canadian Prime Minister Justin Trudeau formally signed the USMCA on November 30, 2018.

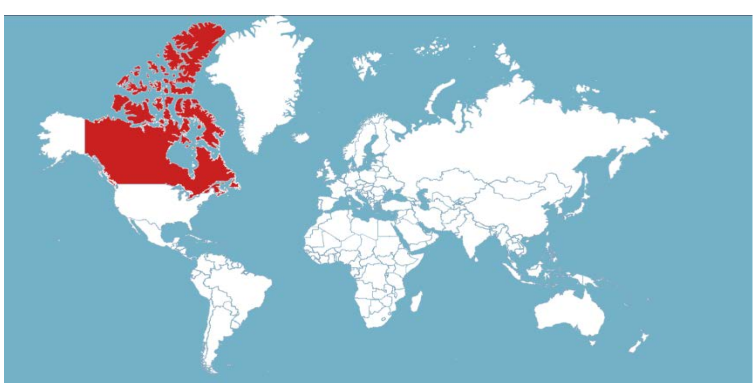
# CANADA

The United States remains the largest exporter of apples to Canada with nearly an 80% market share. Unfortunately, this luxury has been decreasing in recent years due to the influx of apples being imported by Canada from China and other countries in the southern hemisphere. Canada is California's largest export market, and remains one of the largest export markets for the U.S. Apple Export Council (USAEC). Several apple varieties are exported to Canada, with Gala and Granny Smith varieties representing the majority of the volume exported from California.

In 2019, the USAEC has decided to continue the strategy it began in 2018 in the Canadian market. The strategy includes coordinating with California shippers and targeting specific retailers at specific times based on the shipments that were going to Canada, otherwise referred to as, "Following the fruit." Suitable national online publications were selected to run banner ads to advertise a California Apples Crunch for Cash Contest where entrants could win one of 10, $100 gift cards, which resulted in the selection of six media outlets that were geo-targeted to reach primary grocery shoppers. This geo-targeted ad campaign resulted in roughly a 20% increase in imports of California apples in October alone. Due to the successes of 2018, the USAEC plans to continue this strategy during the upcoming season with the hopes of partnering with other commodities to pool resources. Additionally, the USAEC will also be focused on wholesalers or smaller regional retailers that are heavily invested in organics and niche markets. The USAEC will also continue to utilize geo-targeted advertising tactics that will focus on individual zip codes to increase location specificity. The USAEC has found that in addition to the major retailers, these smaller, regional outlets have been increasing their requests for California fruit and USAEC assistance. Finally, the USAEC has allocated additional funding to conduct store audits in both the major retailers and small, regional outlets to establish a sense of whether California apples are present throughout the season and to assist in timing the planned advertising tactics.

The Commission has also been closely monitoring and discussing the current U.S./Canada trade situation. Fortunately, in May 2019, the U.S. reached an agreement with Canada to lift the initial Section 232 tariffs on steel and aluminum, in exchange for Canada removing its retaliatory tariffs against the U.S. The Commission is hopeful that this agreement will eliminate the possibility of future tariff implementation from both the U.S. and Canada, and increase the likelihood of ratifying the new U.S.-Mexico-Canada Free Trade Agreement (USMCA). The Commission is also focused on providing support for the ratification of the USMCA by Congress.

Finally, the Foreign Agricultural Service plans to contribute $90,840 in 2019-2020 on behalf of the California Apple Commission to help maintain the Canadian market.



# MEXICO

In 2019-2020, the Mexico inspection program will begin the final year of the phase-out process for the newly negotiated work plan. In the new work plan, the inspector will arrive in July 2019 for the treatment facility inspection and return to Mexico two days later. The Mexico inspector will not return for any follow up inspections during the season, and USDA-APHIS will be responsible for conducting the remainder of the inspections. From now on, the inspector will only visit California every third year to certify the shippers interested in exporting apples to Mexico.

Additionally, the Commission, in conjunction with USDA-APHIS and Chapman University, was successful in adding irradiation as an additional treatment protocol to the Mexico export program. California apples are now allowed to be irradiated in the U.S. or Mexico (if tarped) as a treatment protocol. California apples are being used as a trial run for other commodities. With the help of Chapman University, research on irradiation of apples will continue throughout the 2019 season. Additionally, Chapman University received federal funding through the most recent USDA Farm Bill to continue their work on irradiation as an alternative treatment method to methyl bromide for apples.

The Commission has also been closely monitoring and discussing the current U.S./Mexico trade situation. In May of 2019, Mexico agreed to remove its 20% retaliatory tariff on U.S. apples in response to the U.S.'s decision to lift the Section 232 tariffs on steel and aluminum. Shortly after, the U.S. announced another set of tariffs (up to 25%) on all goods imported from Mexico until the country agreed to take action on the ongoing border security and immigration concerns. Thankfully, Mexico agreed to increase enforcement efforts regarding border security, and the U.S. responded by lifting the originally planned tariffs. The Commission is hopeful that this agreement will eliminate the possibility of future tariff implementation from both the U.S. and Mexico, and has increased its focus to provide support for the ratification of the U.S.-Mexico-Canada Free Trade Agreement (USMCA) by Congress.

The Foreign Agricultural Service will contribute $17,000 in 2019-2020 on behalf of the California Apple Commission to help maintain this market.

# SOUTH EAST ASIA - INCLUDING TAIWAN

South East Asia (SEA), a region which includes Malaysia, Thailand, Indonesia, Singapore, Vietnam, Taiwan, and the Philippines, has historically been one of California's largest export markets. While the market has declined in importance for California, SEA continues to be a valuable market to the USAEC. Over the last several years, California has relied less on the SEA market for a number of reasons. First, California has not needed to export to SEA in recent years due to the strong domestic market and a smaller Granny Smith crop. Further, competition from China and Washington State have strained the window for California apples in the SEA market. Nearly 80% of China's apple exports are specifically focused on SEA and California is simply not able to compete at these prices. Additionally, the USAEC has been focusing on expanding the presence of other varieties, such as the Empire and Honeycrisp. These varieties of apples are not grown in California, but they are increasing in terms of popularity in growing regions throughout the East Coast and Michigan. The USAEC continues to promote and educate buyers on all U.S. apples, which, in turn, benefits the entire U.S. apple production, including California.

The main competition for California in SEA continues to be China and Washington State. The Commission and the USAEC realize that California will simply not be able to compete with China and Washington State in terms of volume. However, the USAEC's objective has been to compete in terms of quality and therefore extend California's marketing window by several weeks. Since many consumers are concerned with quality and food safety, the USAEC believes the California's marketing window can be extended with precise targeting of specific retailers. According to the USAEC's in country representative, health trends and food safety concerns are the key factors in the development of SEA's retail and wholesale markets. The USAEC will attempt to capitalize on the these factors by "piggy-backing" on the promotional campaigns conducted by the South East Asian governments which are emphasizing the importance of fruit and vegetable consumption to achieve a healthy lifestyle.

The future of the SEA market is uncertain. The current population of 600 million people has been growing significantly over time, and the opportunity for increased apple exports certainly exists. Unfortunately, the SEA market opportunity becomes less available to the U.S. as China increases their total apple production and other countries such as New Zealand, Australia, and Chile increase their ability to store apples long term. It is simply difficult to compete with the lower prices and close proximity of these other apple producing countries. For the USAEC, and more specifically California, remaining successful in the SEA market will require an increased emphasis on size, color, taste, and the safety of the product. This must be emphasized by both the USAEC and specific apple handlers.

In 2019-2020, the Foreign Agricultural Service will contribute $185,000 on behalf of the California Apple Commission to help maintain this market.

# INDIA

Since India has one of the largest middle classes in the world, the U.S. apple industry has been attempting to expand market access for a number of years. In early 2019, the USAEC contracted the services of a new in-country representative in India to facilitate all market activities. Initial difficulties within the Indian market included the lack of infrastructure to transport and store apples. As retail giants such as Costco and Walmart gained access, they began investing in improved infrastructure and transportation methods and, therefore, began to dramatically reduce these initial challenges. Additionally, the retailers' investments were supported by additional outside investments and commitments by the Indian government to open the market to U.S. investments. This made India a very attractive market and helped expand the U.S. apple market share from 100k metric tons in 2009 to over 300k metric tons in 2016. Unfortunately, this growth has been stymied by the implementation of a 75% tariff on all U.S. apples being imported into India in 2019.

In early 2018, India notified the World Trade Organization of their intention to impose a retaliatory tariff on U.S. apples, among other goods, in response to the U.S.'s tariffs on steel and aluminum from India. The proposed tariff of 25% will be added to the existing 50% tariff, thus totaling a 75% tariff on fresh U.S. apples to India. The tariff was initially set to be implemented on August 4, 2018, and after being delayed seven times, was officially applied on June 16, 2019.

For California specifically, India is not a market of priority. The varieties grown in California and the availability of California apples are not conducive to California's marketing/shipping window to India. That being said, the Commission supports the U.S. Apple Export Council's push to gain a larger market segment for other U.S. apple producing states. If large volumes of apples from Washington State and the Eastern U.S. are exported to India, it would greatly decrease the pressure domestically and could ease the pressure on localized export markets such as Mexico and Canada. India has historically been a market of great importance for Washington State, and they exported over 8 million boxes in 2017-18, despite the 50% tariff. However, their exports were reportedly down roughly 66% thus far in 2019, and are expected to continue to decline as a result of the recent 25% additional retaliatory tariff implementation.

The Foreign Agricultural Service and the U.S. Apple Export Council will contribute $140,004 on behalf of the California Apple Commission to help maintain this market.

# RUSSIA AND THE EU

Unfortunately, the ban on western products to Russia is still in effect. This not only has an effect on the U.S., but it has also resulted in a ripple throughout the global apple industry. Initially, it was anticipated that China would fill the majority of the western apple export gap through traditional avenues, and other avenues would be utilized by Poland in order to meet Russia's demand. While China did account for roughly 15% of total apple exports to Russia in 2018, Moldova is by far the main supplier of apples to the Russian market, accounting for 28.3% of total Russian imports. Russia has also imported a significant amount of apples from Serbia and Azerbaijan, and despite sanctions imposed by the Government of Russia Federation, small amounts of apples were also imported from Poland and the Ukraine via back channels.

While apple exports from China to Russia have increased over the past year, the amount of apples that did go to Russia from China have done little to alleviate the pressure on the overall international market. China has instead continued to remain heavily focused on exporting to SEA. While Poland has used other avenues to export apples to Russia, they have continued to remain heavily focused on the EU market. In addition, Poland has been aggressively pursuing access into the U.S. by claiming that they should fall under the parameters of the existing EU work plan. This is extremely problematic and would result in additional pressure on an already overcrowded domestic market. As of now, access has not been granted and the current political climate in regards to trade agreements could work in favor of the U.S.

The EU has been notorious for implementing strict pesticide regulations in the past, and continues to disrupt trade opportunities for U.S. apples. Specifically, EU action on pesticides, particularly diphenylamine (DPA) and morpholine wax, have eroded the U.S.'s access for apples to the EU market. While California does not ship to the EU, these regulations heavily affect the East Coast apple producing states. The East Coast must now find new markets for these apples, thus increasing competition for California in both the domestic and alternative international markets. Additionally, the EU has historically purchased significant volumes of specific varieties, such as Empire and Macintosh. However, with trade volumes to the EU in decline, the U.S. must now find alternative outlets for these varieties, thus placing undue pressure on other varieties that California does produce, such as Gala.

Due to the consistent decline in U.S. apples shipments to the EU, the USAEC decided not to allocate funding for this market in 2018-19. However, the USAEC will continue to fund and participate with a booth at the Fruit Logistica trade show held annually in Berlin.

# LATIN AMERICA

The Latin American region refers to the countries within both South and Central America. This region is not a major market of concern for California specifically, however California exported a small amount of apples to both Columbia and El Salvador in 2018/2019. While California is not specifically focused on this market, other states in the U.S. have been relying on these markets more since the implementation of tariffs on other key U.S. apple export markets. Increasing exports to Latin American will potentially eliminate pressure on markets that California does ship to, such as Mexico.

In 2019, members from the USAEC traveled to Columbia and Peru to conduct a trade mission aimed to increase overall U.S. apple shipments to these markets in addition to gain further market information. The strategy in the Latin American market thus far has been to conduct broad-scale retail promotions during the U.S. apple shipping season without limiting working relationships to specific retailers or importers. The USAEC has found that volumes tend to fluctuate between importers from season to season, depending on price and availability, and it was more feasible to focus on a larger group of retailers/importers rather than a specific few. With this, the USAEC aims to conduct in-store promotions with at least two supermarket chains this year, and implement cooking workshops and recipe sampling programs for consumers. The USAEC has previously coordinated a school program and other activities targeting children. The purpose of these projects was to provide information to kids about U.S. apple varieties and the importance of fruit and vegetables in a nutritious diet. This year, however, the USAEC did not find significant value in this approach, and decided to allocate these funds elsewhere. Further, technical training has been one of the most important activities conducted in Central America for the trade. The purpose of this is to educate supermarkets, importers, and retailers' personnel in order to assure greater quality product, proper handling procedures, and lesser product damage, all factors that can negatively impact sales.

The Foreign Agricultural Service and the USAEC will commit $343,000 in 2019-2020 to maintain and establish a market in Latin America (Central and South America combined). A total of $196,515 in Agricultural Trade Promotion (ATP) funding was also received to launch activities in Brazil, a new market for the USAEC. In early 2019, the U.S. was granted market access to Brazil following the completion of successful negotiations on a systems approach between the two countries. The USAEC plans to explore opportunities in the Brazilian market in 2019. The USAEC has also applied for ATP Funds in South America specifically as part of the second round of available funds through the Foreign Agricultural Service for 2019-2020.

# CHINA

China continues to be the world's largest producer of both fresh and processed apples. In 2018, they produced a total of 31 million tons, their lowest level of apple production in the past 9 years. This decline in production was mainly due to weather events that affected their crop, and China is expected to resume normal levels of production in 2019-2020. Until recently, China's domestic production has historically been consumed by the Chinese population. However, with rising unemployment and an economy that remains sluggish, China is expected to increase its focus on exports.

In 2018, China exported 17.3% of the world's total exported apples, positioning themselves as the top exporter of apples.  As China's apple production rises, China will continue to rely more on exports to neighboring countries, particularly South East Asia. Additionally, China was recently granted access to export apples to the U.S. Apple exports to the U.S. from China are currently minimal; however, there is potential for dramatic increases due to their large volume and overall demand for apples within the U.S. Due to recent trade conflicts between the U.S. and China, there is a 40% retaliatory tariff being applied to all apples exported from the U.S. to China. This radically decreases the competitiveness of U.S. apples in China and could significantly affect exports from Washington. Since California does not currently export apples to China, California is more concerned with the ripple effect this disruption will have on other international and domestic markets.

# ISRAEL

The process of establishing access into the Israeli market for U.S. apples has been difficult and burdensome. Shipments to Israel have been limited to only a few shippers, all of which are located on the East Coast, due to the country's strict phytosanitary issues and pest control measures. Since California does not have a proximity or varietal advantage, California does not currently view Israel as a market of potential. However, the USAEC sees Israel as a potential niche market for apples from the East Coast. Packers from the East Coast have been reluctant to export to Israel in any significant volume due to the high risks involved with shipment rejection concerns. The USAEC continued its partnership with their current in-market representative throughout 2018-2019. The USAEC evaluates the potential of each market on an annual basis, and the level of commitment to Israel was discussed in terms of the level of involvement the USAEC wants to commit to for 2019-2020. It was agreed that the USAEC should remain in Israel for the foreseeable future due to the potential shipping window for the East Coast. Additionally, as other markets reduce apple trade opportunities with the U.S., alternative markets will be needed to offset these losses.

The Foreign Agricultural Service and the USAEC will commit $218,775 in 2018-2019 to maintain and establish a market in Israel, primarily for the East Coast.

# MIDDLE EAST

During the 2018-2019 season, the U.S. faced sharp competition from competing apple producing countries when exporting to the Middle East. Exports to the Middle East were down this year compared to previous seasons due to increased prices that resulted from overall lower production levels. The U.S. is finding it difficult to compete with the lower priced apples being imported from countries including Russia, Italy, Poland, Turkey, and the Ukraine. Additionally, the ongoing war in Yemen, coupled with increased taxes in Dubai and Saudi Arabia to cover the cost of the war, are resulting in a 20 percent reduction in the region's overall economy. This is thought to also have an impact on apple imports as Saudi Arabia and Dubai are the two largest markets for U.S. apples in the Middle East.

The Middle East is a new market for the USAEC. Representatives from the USAEC traveled to the Middle East in order to meet with members of the trade and gather a sense of opportunities that might exist for future in-market activities and potential for market expansion. Following the success of this trade mission, the USAEC plans to conduct a number of activities in the Middle East, including: hire in-country representation to facilitate activities; implement retail and wholesale promotions; provide technical trade assistance in order to assure greater quality product, proper handling procedures, and lesser product damage; and establish a social media presence.

The Foreign Agricultural Service and the USAEC will commit $165,000 in 2019-2020 to establish and maintain a market in the Middle East. The USAEC has also applied for ATP Funds in the Middle East specifically as part of the second round of available funds through the Foreign Agricultural Service.

# CALIFORNIA APPLE DOMESTIC AND EXPORT STATISTICS

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2018-2019

### (MEASURED IN 40 lb. BOXES)

| STATE | GALA | GRANNY SMITH | FUJI | CRIPP PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 17,490 | | | | | | **17,490** |
| ARIZONA | 14,316 | 1,112.30 | | | | | **15,428.30** |
| ARKANSAS | 11,601 | | 440 | | | | **12,041** |
| CALIFORNIA | 257,288.30 | 354,122.60 | 93,051 | 47,975 | 2,448 | 15,237 | **770,121.90** |
| COLORADO | 609 | | 49 | 245 | 294 | 196 | **1,393** |
| CONNECTICUT | 245 | | | | | 637 | **882** |
| FLORIDA | 10,776.50 | 2,138 | 2,233 | | 49 | 349 | **15,545.50** |
| GEORGIA | 21,045 | 8,198 | 1,395 | 805 | 7 | 121 | **31,571** |
| HAWAII | 98 | | | | | | **98** |
| ILLINOIS | 22,383.20 | 1,876.70 | 2,095 | 294 | | 84 | **26,732.90** |
| INDIANA | 9,769 | 5,821 | 3,486 | 126 | 168 | 280 | **19,650** |
| IOWA | 966 | | | | | | **966** |
| KENTUCKY | 8,939 | 3,279 | 1,066 | 1,791 | 36 | 146 | **15,257** |
| LOUISIANA | 5,935 | | 605 | | | | **6,540** |
| MAINE | | | 550 | | | | **550** |
| MARYLAND | 2,481 | | 4 | 449 | | 196 | **3,130** |
| MASSACHUSETTS | 539 | | | | | | **539** |
| MICHIGAN | 10,417 | 10,249 | 2,574 | 2,847 | | | **26,087** |
| MINNESOTA | 13,683 | 3,801 | 1,192 | 931 | 306 | 133 | **20,046** |
| MISSISSIPPI | 6,215 | | 55 | | | | **6,270** |
| MISSOURI | 15,800 | 7,593 | 984 | 147 | 70 | 429 | **25,023** |
| NEBRASKA | 6,215 | | 220 | 110 | | | **6545** |
| NEVADA | 43,006 | 19,279 | 18,486 | 6,768 | | | **87,539** |
| NEW HAMPSHIRE | | | | | | 21 | **21** |
| NEW JERSEY | 539 | 844 | 98 | 49 | 98 | 322 | **1,950** |
| NEW MEXICO | 3,905 | 882 | | | | | **4,787** |
| NEW YORK | 13,004 | 2,924 | 858 | 98 | | | **16,884** |
| NORTH CAROLINA | 16,655 | 196 | 2,234 | 98 | 49 | 195 | **19,427** |
| OHIO | 7,091 | 16,288 | 4,727 | 196 | | | **28,302** |
| OKLAHOMA | 15,567 | | 2,445 | | | | **18,012** |
| OREGON | 415 | | | | | | **415** |
| PENNSYLVANIA | 5,559 | 2,254 | 2,274 | 660 | | 343 | **11,090** |
| SOUTH CAROLINA | 960 | 2,730 | 825 | | | | **4,515** |
| TENNESSEE | 9,392 | 6,668 | 1,540 | 660 | | | **18,260** |
| TEXAS | 77,571 | 31,267 | 19,126 | 14,167 | | | **142,131** |
| UTAH | 7,532 | | | 3,513 | | | **11,045** |
| VIRGINIA | 11,204 | 2,540 | | | | | **13,744** |
| WASHINGTON | | 440 | 330 | 110 | | 25 | **905** |
| WISCONSIN | 15,915 | 1,021 | 879 | 676 | | | **18,491** |
| WYOMING | 8,930 | | 440 | | | | **9,370** |
| **TOTAL** | **674,056.00** | **485,523.60** | **164,261.00** | **82,715.00** | **3,525.00** | **18,714.00** | **1,428,794.60** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2017-2018

### (MEASURED IN 40 lb. BOXES)

| STATE | GALA | GRANNY SMITH | FUJI | CRIPP PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 833 | 196 | | | | | **1,029** |
| ARIZONA | 15,402 | 12,684 | 2,952 | 1,876 | 44 | | **32,958** |
| ARKANSAS | 16,638 | 3,338 | 3,420 | | | | **23,396** |
| CALIFORNIA | 353,753 | 163,117.40 | 85,418.40 | 58,328.80 | 2,259 | 16,220 | **679,096.60** |
| COLORADO | 13,291 | 9,120 | 207 | | 383 | 786 | **23,787** |
| CONNECTICUT | 1,127 | 308 | | | | 1,960 | **3,395** |
| FLORIDA | 14,461 | 3,955.60 | 1,156 | | 98 | 973 | **20,643.60** |
| GEORGIA | 58,261.20 | 52,055.70 | 8,825 | | 7 | 497 | **119,645.90** |
| HAWAII | 280 | 515 | | | | | **795** |
| ILLINOIS | 10,380 | 7,154 | 1,586 | 784 | | 321 | **20,225** |
| INDIANA | 12,528 | 7,679 | 1,813 | | 68 | 651 | **22,739** |
| IOWA | 7,104 | 4,981 | | | | | **12,085** |
| KANSAS | 5,697 | 2,778 | 635 | | | | **9,110** |
| KENTUCKY | 12,139 | 8,658 | 1,770 | 559 | 147 | 684 | **23,957** |
| LOUISIANA | 12,011 | 3,233 | 1,020 | | | | **16,264** |
| MAINE | 8,880 | 3,000 | 1,380 | 1,003 | | | **14,263** |
| MARYLAND | 4,326 | 4,036 | 114 | 75 | | 534 | **9,085** |
| MASSACHUSETTS | 2,177 | 4,141 | 294 | | | | **6,318** |
| MICHIGAN | 22,080 | 4,465 | 3,786 | 1,875 | | | **32,206** |
| MINNESOTA | 14,802 | 17,265 | 2,176 | 98 | 410 | 420 | **35,171** |
| MISSISSIPPI | 1,320 | | | | | | **1,320** |
| MISSOURI | 9,896 | 2,882 | 5,880 | | | | **18,658** |
| MONTANA | | | | | | | |
| NEBRASKA | 1,334 | | 2,580 | | | | **3,914** |
| NEVADA | 3,332 | 1,257 | | | | | **4,589** |
| NEW HAMPSHIRE | | | | | | | |
| NEW JERSEY | 87,023 | 36,474 | 2,296 | 490 | 343 | 344 | **126,970** |
| NEW MEXICO | | 980 | | | | | **980** |
| NEW YORK | 8,808 | 16,276 | 7,668 | 477 | | | **16,953** |
| NORTH CAROLINA | 5,490 | 817 | 77 | | 227 | 271 | **6,882** |
| OHIO | 33,762 | 18,563 | 3,971 | | | 98 | **56,394** |
| OKLAHOMA | 8,280 | 5,094 | 5,739 | | | 357 | **19,470** |
| OREGON | 1,470 | 389 | 98 | | 229 | 469 | **2,655** |
| PENNSYLVANIA | 6,511 | 3,302 | 2,041 | 2,311 | 126 | 530 | **12,510** |
| SOUTH CAROLINA | 1,421 | | | | | | **1,421** |
| TENNESSEE | 9,151 | 5,599 | 1,591 | 3,548 | | | **19,889** |
| TEXAS | 114,599 | 35,204 | 17,319 | 5,379 | | 1,263 | **173,764** |
| UTAH | 8,649 | 2,891 | | | | | **11,540** |
| VERMONT | | | | | | | |
| VIRGINIA | 9,282 | 5,593 | 1,568 | | | | **16,443** |
| WASHINGTON | 52,905 | 7,332 | 147 | | 294 | 501 | **61,179** |
| WISCONSIN | 6,743 | 335 | 3,436 | | 28 | 155 | **10,697** |
| WYOMING | 4,392 | | 2,620 | | | | **7,012** |
| **TOTAL** | **951,658.20** | **405,326** | **300,434** | **99,919** | **6,964** | **42,436** | **1,750,856** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2016-2017

### (MEASURED IN 40 lb. BOXES)

| STATE | GALA | GRANNY SMITH | FUJI | PINK LADY | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 6,429 | 588 | 5,640 | | | | **12,657** |
| ARIZONA | 36,216 | 28,494 | 765 | 4,837 | 400 | | **77,312** |
| ARKANSAS | 13,800 | | 3,840 | | | | **17,640** |
| CALIFORNIA | 208,719 | 169,507 | 146,279 | 66,989 | 3,611 | 26,982 | **622,087** |
| COLORADO | 10,465 | 882 | 588 | | 559 | 547 | **13,041** |
| CONNECTICUT | | 686 | 98 | | | | **784** |
| FLORIDA | 58,350 | 8,882 | 10,836 | | 98 | 2,104 | **80,270** |
| GEORGIA | 31,989 | 13,808 | 6,062 | 88 | 98 | | **52,045** |
| HAWAII | 405 | | 1,614 | | | | **2,019** |
| ILLINOIS | 50,886 | 5,546 | 5,140 | | | | **61,573** |
| INDIANA | 19,781 | 1 | 4,367 | | 363 | 1,324 | **25,836** |
| IOWA | 3,905 | 2,086 | 175 | 147 | 7 | | **6,320** |
| KANSAS | 560 | | 176 | | | | **736** |
| KENTUCKY | 10,359 | 419 | 3,584 | | 441 | 1,882 | **16,685** |
| LOUISIANA | 10,197 | 784 | 720 | | | | **11,701** |
| MAINE | 8,880 | 3,000 | 1,380 | 1,003 | | | **14,263** |
| MARYLAND | 436 | 1,302 | 49 | | | 1,470 | **3,257** |
| MASSACHUSETTS | 1,918 | 702 | 294 | | | | **2,914** |
| MICHIGAN | 30,174 | 2,922 | 4,507 | | | | **37,603** |
| MINNESOTA | 24,279 | 42,951 | 6,099 | 1,212 | 294 | 1,987 | **76,823** |
| MISSISSIPPI | 10,143 | 98 | 2,640 | | | | **12,881** |
| MISSOURI | 28,121 | 1,958 | 4,679 | | | | **34,758** |
| MONTANA | | | | | | | |
| NEBRASKA | 10,620 | | 180 | | | | **10,800** |
| NEVADA | 12,019 | 21,686 | 14,809 | 5,065 | | | **53,579** |
| NEW HAMPSHIRE | | 70 | | | | | **70** |
| NEW JERSEY | 1,653 | 1,504 | | | 47 | | **3,204** |
| NEW MEXICO | 16,100 | 10,329 | 2,820 | 240 | | | **29,489** |
| NEW YORK | 10,811 | 16,276 | 3,525 | 1,564 | | | **32,176** |
| NORTH CAROLINA | 16,502 | 247 | 4,285 | | 49 | 1,407 | **22,490** |
| OHIO | 34,717 | 836 | 5,943 | | | 686 | **42,182** |
| OKLAHOMA | 16,406 | 12,214 | 4,020 | 4,100 | | | **36,740** |
| OREGON | 70 | 46 | 98 | | 49 | 70 | **333** |
| PENNSYLVANIA | 26,187 | 24,401 | 7,969 | 2,311 | | 364 | **61,232** |
| SOUTH CAROLINA | 11,620 | 441 | 2,040 | | | | **14,101** |
| TENNESSEE | 15,066 | 2,352 | 3,479 | | | | **20,897** |
| TEXAS | 83,273 | 20,873 | 16,661 | 8,012 | 23 | 3,422 | **132,264** |
| UTAH | 30,975 | 3,120 | 9,747 | 4,350 | | | **48,192** |
| VERMONT | | | 98 | | 484 | | **582** |
| VIRGINIA | 13,200 | 196 | 2,141 | | | | **15,537** |
| WASHINGTON | 6,144 | 3,430 | 3,128 | | 98 | 191 | **12,991** |
| WISCONSIN | 19,219 | 2,688 | 3,157 | | 343 | | **25,407** |
| WYOMING | 5,180 | | 200 | | | | **5,380** |
| **TOTAL** | **895,776** | **405,326** | **300,434** | **99,919** | **6,964** | **42,436** | **1,750,856** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES
# DOMESTIC SHIPMENTS 2015-2016
### (MEASURED IN 40 lb. BOXES)

| STATE | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 21,302 | 455 | 1,552 | | | | 23,309 |
| ALASKA | 217 | | | | | | 217 |
| ARIZONA | 28,834 | 15,001 | 735 | 2,596 | | | 47,166 |
| ARKANSAS | 10,214 | 160 | 325 | | | | 10,699 |
| CALIFORNIA | 240,232 | 163,692 | 120,450 | 49,540 | 8,910 | 29,721 | 612,547 |
| COLORADO | 6,853 | 441 | 540 | | 196 | 119 | 8,149 |
| CONNECTICUT | 196 | 49 | | | | | 245 |
| FLORIDA | 57,843 | 10,004 | 5,635 | 25 | 266 | 119 | 73,892 |
| GEORGIA | 25,217 | 12,066 | 4,220 | | | | 41,503 |
| HAWAII | 392 | | 645 | | | | 1,037 |
| ILLINOIS | 42,631 | 21,879 | 7,268 | 490 | 441 | 322 | 73,031 |
| INDIANA | 25,827 | 4,375 | 2,394 | | 357 | 47 | 33,000 |
| IOWA | 3,159 | 2,266 | 49 | 56 | 21 | | 5,551 |
| KANSAS | 1,880 | 147 | | 595 | | | 2,622 |
| KENTUCKY | 15,272 | 848 | 1,313 | | 390 | 190 | 18,013 |
| LOUISIANA | 14,208 | 4,599 | 2,991 | | | | 21,798 |
| MAINE | 8,515 | 3,398 | | | | | 11,913 |
| MARYLAND | 588 | 2,122 | 49 | | | | 2,759 |
| MASSACHUSETTS | 4,760 | 2,425 | 309 | 877 | 27 | 98 | 8,496 |
| MICHIGAN | 23,078 | 3,692 | 7,090 | 98 | 98 | | 34,056 |
| MINNESOTA | 8,128 | 32,437 | 147 | 1,922 | 1,058 | 539 | 44,231 |
| MISSISSIPPI | 12,558 | 195 | 969 | | | | 13,722 |
| MISSOURI | 31,929 | 7,839 | 5,605 | | | | 45,373 |
| NEBRASKA | 11,887 | 260 | | | | | 12,147 |
| NEVADA | 14,280 | 9,782 | 9,045 | 4,144 | | | 37,251 |
| NEW HAMPSHIRE | 98 | 196 | | | | 21 | 315 |
| NEW JERSEY | 2,800 | 2,366 | 35 | | 391 | 98 | 5,690 |
| NEW MEXICO | 18,311 | 14,588 | 2,176 | 2,278 | 301 | | 37,654 |
| NEW YORK | 15,790 | 18,715 | 2,161 | 294 | | | 36,960 |
| NORTH CAROLINA | 18,743 | 4,611 | 3,825 | | 112 | | 27,291 |
| OHIO | 34,639 | 5,433 | 4,923 | | 145 | 98 | 45,238 |
| OKLAHOMA | 18,967 | 7,795 | 4,005 | | | | 30,767 |
| OREGON | 539 | 882 | 98 | | 82 | 31 | 1,632 |
| PENNSYLVANIA | 24,206 | 21,171 | 5,475 | 1,029 | | | 51,881 |
| RHODE ISLAND | 1 | | | | | | 1 |
| SOUTH CAROLINA | 11,775 | 260 | 520 | | | | 12,555 |
| TENNESSEE | 8,586 | 2,906 | 946 | | | | 12,438 |
| TEXAS | 101,285 | 37,828 | 13,882 | 11,278 | 178 | 49 | 164,500 |
| UTAH | 26,866 | 3,499 | 2,786 | | | | 33,151 |
| VIRGINIA | 6,611 | 130 | | | | | 6,741 |
| WASHINGTON | 4,601 | 244 | | | | | 4,845 |
| WISCONSIN | 22,636 | 4,365 | 4,330 | | | | 31,331 |
| WYOMING | 4,110 | 2,836 | 1,365 | | | | 8,311 |
| **TOTAL** | **930,566** | **425,958** | **217,859** | **75,222** | **12,973** | **31,452** | **1,694,032** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2014-2015

**(MEASURED IN 40 lb. BOXES)**

| STATE | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 19,241 | 3,962 | 1,369 | 1,950 | | | 26,522 |
| ARIZONA | 14,444 | 24,323 | 4,745 | 582 | 49 | | 44,143 |
| ARKANSAS | 8,005 | 455 | 65 | 975 | | | 9,500 |
| CALIFORNIA | 189,811 | 275,407 | 124,793 | 12,261 | 3,236 | 55,912 | 661,422 |
| COLORADO | 1,666 | 8,363 | 2,932 | | 525 | 1,846 | 15,332 |
| CONNECTICUT | 203 | 49 | | | | | 252 |
| FLORIDA | 41,915 | 15,708 | 9,603 | 2,517 | 49 | 308 | 70,100 |
| GEORGIA | 17,531 | 16,499 | 4,928 | 975 | 147 | 49 | 40,129 |
| HAWAII | 121 | | | | | | 121 |
| ILLINOIS | 23,628 | 16,548 | 8,195 | 2,296 | 443 | 1,078 | 52,188 |
| INDIANA | 21,419 | 5,479 | 2,674 | 2,656 | 273 | 1,596 | 34,097 |
| IOWA | 2,805 | 6,327 | 166 | | 93 | | 9,391 |
| KANSAS | 759 | 3,001 | 25 | | 98 | | 3,883 |
| KENTUCKY | 8,443 | 1,450 | 294 | 975 | | 392 | 11,554 |
| LOUISIANA | 5,855 | 2,685 | 2,579 | 1,460 | | | 12,579 |
| MAINE | 5,155 | 1,011 | | 975 | | | 7,141 |
| MARYLAND | 774 | 8,267 | 98 | | | 929 | 10,068 |
| MASSACHUSETTS | 6,523 | 21,987 | 735 | 1,521 | 98 | 772 | 31,636 |
| MICHIGAN | 11,469 | 5,176 | 6,129 | | 97 | | 22,871 |
| MINNESOTA | 3,224 | 32,643 | 182 | 294 | 977 | 250 | 37,570 |
| MISSISSIPPI | 3,642 | 650 | 780 | 843 | | | 5,915 |
| MISSOURI | 20,588 | 8,420 | 5,560 | 2,360 | | | 36,928 |
| NEBRASKA | 10,673 | 520 | 650 | 1,235 | | | 13,078 |
| NEVADA | 11,446 | 11,657 | 1,225 | 975 | | | 25,303 |
| NEW HAMPSHIRE | | | | | | 143 | 143 |
| NEW JERSEY | 539 | 17,332 | 1,176 | | | 224 | 19,271 |
| NEW MEXICO | 7,595 | 11,026 | 1,865 | 650 | | | 21,136 |
| NEW YORK | 7,274 | 46,356 | 2,164 | 1,612 | 28 | 14 | 57,448 |
| NORTH CAROLINA | 13,728 | 5,187 | 3,479 | 975 | 30 | 87 | 23,486 |
| OHIO | 27,916 | 8,354 | 4,554 | 1,967 | | 954 | 43,745 |
| OKLAHOMA | 14,000 | 2,930 | 3,161 | 1,820 | | | 21,911 |
| OREGON | 2,450 | 98 | 49 | | 98 | 216 | 2,911 |
| PENNSYLVANIA | 22,817 | 34,032 | 3,859 | 2,275 | 355 | 1,005 | 64,343 |
| SOUTH CAROLINA | 10,182 | 1,531 | 455 | 649 | | | 12,817 |
| TENNESSEE | 7,364 | 5,156 | 1,040 | 975 | | | 14,535 |
| TEXAS | 93,389 | 66,219 | 19,958 | 12,899 | 98 | 3,117 | 195,680 |
| UTAH | 5,819 | 3,138 | 1,820 | 650 | | | 11,427 |
| VIRGINIA | 14,345 | 4,890 | 1,550 | 1,170 | | | 21,955 |
| VERMONT | | | 14 | | | 35 | 49 |
| WASHINGTON | 6,798 | 11,134 | | 650 | | 145 | 18,727 |
| WISCONSIN | 9,782 | 2,810 | 3,306 | 975 | | | 16,873 |
| WYOMING | 15,203 | 2,025 | 1,340 | 650 | | | 19,218 |
| **TOTAL** | **688,547** | **692,806** | **227,517** | **62,767** | **6,694** | **69,072** | **1,747,405** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2013-2014

**(MEASURED IN 40 lb. BOXES)**

| STATE | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 17,359 | 940 | | 98 | 294 | | 18,692 |
| ARIZONA | 21,303 | 10,779 | 1,618 | 4,035 | 427 | | 38,162 |
| ARKANSAS | 11,709 | | | | | | 11,709 |
| CALIFORNIA | 223,144 | 426,553 | 173,135 | 102,500 | 8,041 | 36,557 | 969,932 |
| COLORADO | 3,396 | 1,979 | 359 | 70 | 196 | 1,48 | 7,481 |
| CONNECTICUT | 851 | | | | | | 851 |
| DIST. OF COLUMBIA | 931 | | | | | | 931 |
| FLORIDA | 31,727 | 6,234 | 3,909 | 70 | 583 | 469 | 42,993 |
| GEORGIA | 12,703 | 9,871 | 3,587 | | 441 | 49 | 26,651 |
| HAWAII | 405 | 98 | 1,785 | | | | 2,288 |
| ILLINOIS | 41,011 | 5,532 | 3,968 | 2,695 | | 442 | 53,648 |
| INDIANA | 16,402 | 18,087 | 1,632 | 533 | | 728 | 37,382 |
| IOWA | 2,403 | 3,925 | 1,715 | 903 | 1,078 | | 10,024 |
| KANSAS | | | | 430 | | | 430 |
| KENTUCKY | 10,043 | 5,902 | 245 | 80 | 490 | 523 | 17,283 |
| LOUISIANA | 4,822 | 83 | 1,785 | 15 | | | 6,705 |
| MAINE | 1,950 | 1,666 | | | | | 3,616 |
| MARYLAND | 1,798 | 196 | 128 | 441 | 14 | 642 | 3,219 |
| MASSACHUSETTS | 5,612 | 14,423 | 2,372 | 2,691 | 343 | 1,116 | 26,557 |
| MICHIGAN | 8,770 | 8,987 | 5,375 | | 224 | | 23,356 |
| MINNESOTA | 1,920 | 23,794 | 441 | 828 | 1,597 | 405 | 28,985 |
| MISSISSIPPI | 7,152 | | | | | | 7,152 |
| MISSOURI | 26,910 | 3,136 | 2,190 | 490 | | | 32,726 |
| NEVADA | 9,787 | 13,275 | 49 | | | | 23,111 |
| NEW HAMPSHIRE | 77 | 294 | 98 | | 371 | 147 | 987 |
| NEW JERSEY | 1,225 | 7,109 | 296 | 889 | 752 | 1,246 | 11,517 |
| NEW MEXICO | 13,368 | 93 | 142 | | 28 | | 13,631 |
| NEW YORK | 5,804 | 18,127 | 1,050 | 2,564 | 1,225 | | 28,770 |
| NORTH CAROLINA | 9,202 | 3,418 | 3,129 | | 21 | 70 | 15,840 |
| OHIO | 18,018 | 5,054 | 6,986 | 2,366 | | 852 | 33,276 |
| OKLAHOMA | 20,949 | | | | | | 20,949 |
| OREGON | 147 | 1,591 | | | 49 | 314 | 2,101 |
| PENNSYLVANIA | 13,292 | 21,603 | 4,659 | 885 | 337 | 1,420 | 42,196 |
| SOUTH CAROLINA | 3,345 | 352 | | 49 | | | 3,746 |
| TENNESSEE | 5,690 | 5,647 | | 2,532 | | | 13,869 |
| TEXAS | 99,327 | 126,276 | 3,950 | 16,169 | 920 | 1,463 | 248,105 |
| UTAH | 16,700 | 2,614 | | 1,195 | | | 20,509 |
| VIRGINIA | 1,847 | 2,221 | | | 784 | | 4,852 |
| WASHINGTON | 10,019 | 49,734 | | | | 98 | 59,851 |
| WISCONSIN | 2,430 | 28 | 2,249 | | 49 | | 4,756 |
| WYOMING | 2,976 | | | | | | 2,976 |
| **TOTAL** | **686,538** | **799,625** | **226,852** | **142,530** | **18,264** | **48,022** | **1,921,832** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2012-2013

**(MEASURED IN 40 lb. BOXES)**

| STATE | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 7,357 | 9,864 | 186 | | | | 17,407 |
| ARIZONA | 17,341 | 16,655 | 4,374 | 1,294 | 21 | | 39,685 |
| ARKANSAS | 3,998 | | | | | | 3,998 |
| CALIFORNIA | 216,877 | 297,090 | 94,785 | 45,606 | 5,645 | 15,727 | 678,730 |
| COLORADO | 12,799 | 8,610 | 2,401 | 266 | 125 | 1,674 | 25,875 |
| CONNECTICUT | 343 | 539 | | | | | 882 |
| FLORIDA | 32,641 | 16,582 | 4,880 | 29 | | 98 | 54,230 |
| GEORGIA | 19,698 | 16,398 | 8,218 | 2,940 | 147 | | 47,401 |
| HAWAII | 1,079 | 1,027 | 1,244 | | | | 3,347 |
| IDAHO | 490 | | | | | | 490 |
| ILLINOIS | 27,676 | 14,968 | 1,581 | 9,124 | 411 | 1,238 | 54,998 |
| INDIANA | 10,106 | 6,154 | 3,357 | | 98 | 671 | 20,386 |
| IOWA | 952 | 3,846 | 98 | 294 | 1,019 | | 6,209 |
| KANSAS | 2,500 | 819 | | 294 | | | 3,613 |
| KENTUCKY | 7,181 | 24,046 | 260 | | 196 | 98 | 31,781 |
| LOUISIANA | 2,413 | 1,664 | 4,164 | | | | 8,241 |
| MAINE | 854 | 6,514 | | | | | 7,368 |
| MARYLAND | 3,528 | 12,831 | 2,037 | 1,390 | 14 | 532 | 20,332 |
| MASSACHUSETTS | 13,181 | 20,379 | 3,087 | 1,420 | 392 | 21 | 38,480 |
| MICHIGAN | 20,278 | 21,915 | 18,758 | | 21 | | 60,972 |
| MINNESOTA | 2,010 | 43,745 | 693 | 581 | 695 | 2,049 | 49,773 |
| MISSISSIPPI | 6,829 | | | | | | 6,829 |
| MISSOURI | 23,265 | 19,175 | 3,049 | | | | 45,489 |
| MONTANA | 196 | | | 182 | | | 378 |
| NEBRASKA | 1,708 | | | | | | 1,708 |
| NEVADA | 3,450 | 10,680 | 296 | | | | 14,426 |
| NEW HAMPSHIRE | 147 | 245 | 52 | | | 1,459 | 1,903 |
| NEW JERSEY | 603 | 10,569 | 472 | | | 1,299 | 12,943 |
| NEW MEXICO | 3,899 | 147 | | | | | 4,046 |
| NEW YORK | 10,400 | 28,939 | 1,205 | 1,716 | 56 | 42 | 42,358 |
| NORTH CAROLINA | 2,399 | 4,811 | 1,313 | | | | 8,523 |
| NORTH DAKOTA | | 209 | | | | | 209 |
| OHIO | 22,938 | 10,808 | 2,874 | 1,743 | 49 | 980 | 39,392 |
| OKLAHOMA | 9,288 | 49 | 455 | | | | 9,792 |
| OREGON | 3,309 | 2,891 | | 686 | | 137 | 7,023 |
| PENNSYLVANIA | 14,849 | 27,839 | 1,889 | 4,471 | 35 | 1,310 | 50,393 |
| SOUTH CAROLINA | 2,764 | 3,136 | | | | | 5,900 |
| TENNESSEE | 9,751 | 7,925 | | 490 | | | 18,166 |
| TEXAS | 81,150 | 84,894 | 9,104 | 19,239 | 978 | 2,551 | 197,916 |
| UTAH | 11,847 | 777 | 399 | 1,540 | 35 | | 14,598 |
| VERMONT | 49 | | | | | | 49 |
| VIRGINIA | 1,894 | 2,296 | 377 | | | | 4,567 |
| WASHINGTON | 9,238 | 14,858 | 134 | 1,070 | 147 | | 5,447 |
| WISCONSIN | 7,845 | 294 | 287 | 91 | 444 | | 8,961 |
| WYOMING | 5,178 | | 175 | | | | 5,353 |
| **TOTAL** | **639,296** | **754,189** | **172,204** | **94,466** | **10,528** | **29,886** | **1,700,568** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2011-2012

**(MEASURED IN 40 lb. BOXES)**

| STATE | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 14,602 | 14,319 | | 147 | | | 29,068 |
| ARIZONA | 33,583 | 27,018 | 3,405 | 5,160 | | 1,653 | 70,819 |
| ARKANSAS | 9,425 | | | | | | 9,425 |
| CALIFORNIA | 187,132 | 251,077 | 102,186 | 48,385 | 2,600 | 60,198 | 651,580 |
| COLORADO | 18,294 | 15,684 | 3,009 | 1,596 | 303 | 1,429 | 4,0316 |
| CONNECTICUT | 3,388 | 1,568 | 98 | | | | 5,054 |
| DIST. OF COLUMBIA | 196 | 196 | | | | 686 | 1,078 |
| FLORIDA | 35,384 | 30,768 | 2,588 | | 21 | 3,174 | 71,935 |
| GEORGIA | 31,182 | 17,718 | 7,505 | 2,450 | | 3,058 | 61,913 |
| HAWAII | 294 | 98 | 343 | | | | 735 |
| IDAHO | 133 | 539 | | | | | 672 |
| ILLINOIS | 41,511 | 35,830 | 4,893 | 3,920 | 245 | 5,609 | 92,009 |
| INDIANA | 34,460 | 31,970 | 3,103 | | 210 | 2,925 | 72,668 |
| IOWA | 483 | 5,497 | 32 | | 234 | | 6,246 |
| KANSAS | 2,604 | 4,440 | 198 | 588 | | 1,675 | 9,506 |
| KENTUCKY | 14,240 | 23,990 | 882 | | 147 | 1,397 | 40,656 |
| LOUISIANA | 13,133 | 5,045 | 3,220 | | | | 21,398 |
| MAINE | 1,631 | 11,870 | | | | | 13,501 |
| MARYLAND | 6,451 | 17,761 | 21,655 | 7,028 | | 3,155 | 56,050 |
| MASSACHUSETTS | 4,949 | 37,752 | 4,655 | 6,909 | 156 | 8,272 | 62,693 |
| MICHIGAN | 26,632 | 21,455 | 7,670 | 196 | 420 | 4,953 | 61,326 |
| MINNESOTA | 11,598 | 54,720 | 49 | 2,429 | 1,742 | 19,808 | 90,347 |
| MISSISSIPPI | 3,705 | 3,045 | | | | | 6,750 |
| MISSOURI | 2,7841 | 16,293 | 5,754 | 1,637 | | 3,466 | 54,992 |
| MONTANA | 245 | 1,077 | | | | | 1,322 |
| NEBRASKA | 7,605 | 7,163 | | 168 | | | 14,936 |
| NEVADA | 7,319 | 7,323 | 245 | | | 1,134 | 16,021 |
| NEW HAMPSHIRE | 350 | 420 | | | 21 | 290 | 1,081 |
| NEW JERSEY | 6,344 | 18,777 | 196 | | 14 | 812 | 26,143 |
| NEW MEXICO | 11,473 | 5,948 | 49 | | | | 17,470 |
| NEW YORK | 8,182 | 36,120 | 2,128 | 3,393 | | 5,186 | 55,009 |
| NORTH CAROLINA | 8,000 | 24,677 | 2,974 | 416 | 63 | 273 | 36,404 |
| NORTH DAKOTA | | 28 | | 40 | | 147 | 215 |
| OHIO | 42,361 | 24,357 | 7,017 | 539 | 98 | 1,428 | 75,800 |
| OKLAHOMA | 13,444 | 12,475 | 1,533 | | 145 | 49 | 27,646 |
| OREGON | 2,685 | 4,004 | 196 | | | 962 | 7,848 |
| PENNSYLVANIA | 19,164 | 33,233 | 2,856 | 7,894 | 258 | 3,615 | 67,020 |
| RHODE ISLAND | | 147 | | | | | 147 |
| SOUTH CAROLINA | 1,160 | 10,472 | | | | 294 | 11,926 |
| TENNESSEE | 15,619 | 12,703 | | 1,746 | | 2,058 | 32,127 |
| TEXAS | 91,224 | 93,039 | 6,795 | 19,445 | 441 | 7,071 | 21,8016 |
| UTAH | 27,451 | 13,053 | 4,420 | 735 | | 98 | 45,757 |
| VERMONT | 196 | 49 | | | | | 245 |
| VIRGINIA | 8,295 | 11,546 | 686 | | | 1,134 | 21,661 |
| WASHINGTON | 18,581 | 28,204 | 6,569 | | 49 | 7,093 | 60,496 |
| WISCONSIN | 8,934 | 10,636 | 665 | 196 | 33 | 637 | 21,101 |
| WYOMING | 18,420 | 5,235 | 1,820 | | | | 25,475 |
| **TOTAL** | **839,913** | **989,347** | **209,396** | **115,018** | **7,201** | **153,739** | **2,314,612** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2010-2011

**(MEASURED IN 40 lb. BOXES)**

| STATE | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 14,342 | 49 | | | | | 14,391 |
| ARIZONA | 59,031 | 42,189 | 714 | 490 | 1,593 | 269 | 104,286 |
| ARKANSAS | 3,960 | 3,700 | | | | | 7,660 |
| CALIFORNIA | 336,880 | 360,229 | 258,476 | 84,676 | 16,105 | 27,485 | 1,083,854 |
| COLORADO | 10,817 | 6,159 | 2,093 | 1,909 | 49 | 1,225 | 22,252 |
| CONNECTICUT | | 2940 | | | | | 2,940 |
| DIST. OF COLUMBIA | 854 | 784 | 98 | | | | 1,736 |
| FLORIDA | 25,780 | 13,003 | 4,368 | 240 | 128 | 499 | 44,018 |
| GEORGIA | 20,929 | 15,512 | 4,246 | 1,078 | | 927.1 | 42,692 |
| HAWAII | 987 | 123 | 441 | | | | 1,551 |
| ILLINOIS | 40,796 | 25,316 | 4,796 | | | 538 | 71,447 |
| INDIANA | 16,546 | 9,054 | 4,375 | | 98 | 1,939 | 32,012 |
| IOWA | 2,072 | 2,058 | | | 49 | | 4,179 |
| KANSAS | 98 | 98 | | 1,073 | | | 1,269 |
| KENTUCKY | 14,323 | 1,074 | 147 | 5,880 | 514 | | 21,938 |
| LOUISIANA | 4,234 | 5,499 | 1,995 | | | | 11,728 |
| MAINE | 1,738 | 17,983 | | | | | 19,721 |
| MARYLAND | 3,647 | 23,335 | 1,239 | 2,177 | | 1,470 | 31,868 |
| MASSACHUSETTS | 4,879 | 56,419 | 2,205 | 5,376 | 245 | | 69,124 |
| MICHIGAN | 5,150 | 14,247 | 6,037 | 652 | 245 | | 26331 |
| MINNESOTA | 9,996 | 49,460 | 245 | 2,695 | 326 | 441 | 63,163 |
| MISSISSIPPI | 6,039 | | | | | | 6,039 |
| MISSOURI | 15,068 | 10,924 | 2,660 | 1,470 | 98 | | 30,221 |
| MONTANA | | | | 49 | | | 49 |
| NEBRASKA | 4,175 | | | | | | 4,175 |
| NEVADA | 18,566 | 24,762 | 49 | | | | 43,377 |
| NEW HAMPSHIRE | 441 | 147 | | | 147 | 288 | 1,023 |
| NEW JERSEY | 7,135 | 23,917 | 985 | 273 | | 1,331 | 33,641 |
| NEW MEXICO | 11,296 | 2,798 | 244 | | 98 | | 14,436 |
| NEW YORK | 7,020 | 68,482 | 1,905 | 1,118 | 98 | | 78,624 |
| NORTH CAROLINA | 12,746 | 6,768 | 4,011 | 50 | 529 | 1 | 24,105 |
| NORTH DAKOTA | 98 | | | | | | 98 |
| OHIO | 13,440 | 5,911 | 5,295 | 5,864 | | 190 | 30,700 |
| OKLAHOMA | 12,915 | 8,098 | 1,934 | 196 | | | 23,143 |
| OREGON | 7,470 | 947 | 2,176 | 486 | 87 | 273 | 11,439 |
| PENNSYLVANIA | 24,328 | 27,605 | 4,684 | 1,078 | 539 | 378 | 58,612 |
| SOUTH CAROLINA | 6,650 | 7,806 | | | | | 14,456 |
| TENNESSEE | 13,569 | 6,692 | 1,862 | 1,862 | | | 23,985 |
| TEXAS | 102,382 | 74,606 | 10,105 | 24,338 | 1,835 | 1,883 | 215,150 |
| UTAH | 22,768 | 147 | 116 | 490 | 28 | | 23,549 |
| VIRGINIA | 6,860 | 4,508 | | 637 | | | 12,005 |
| WASHINGTON | 9,543 | 13,650 | 4,620 | | | 196 | 28,009 |
| WEST VIRGINIA | | | | 3 | | | 28,009 |
| WISCONSIN | 9,943 | 5,528 | 1,610 | 539 | | | 17,620 |
| WYOMING | 8,590 | 5,637 | 2,240 | | | | 16,467 |
| **TOTAL** | **898,106** | **948,167** | **335,972** | **144,701** | **22,812** | **39,334** | **2,389,092** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2009-2010

**(MEASURED IN 40 lb. BOXES)**

| STATE | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 22,663 | | | | | | 22,663 |
| ARIZONA | 26,552 | 1,9541 | 3,420 | 2,798 | | 91 | 52,402 |
| ARKANSAS | 13,630 | 3,885 | | | | | 17,515 |
| CALIFORNIA | 149,145 | 369,232 | 102,671 | 56,641 | 9,459 | 7,272 | 694,421 |
| COLORADO | 8,166 | 4,477 | 6,486 | 1,253 | 955 | 625 | 21,962 |
| CONNECTICUT | 588 | 1,813 | | | | | 2,401 |
| DIST. OF COLUMBIA | 196 | 98 | | | | | 294 |
| FLORIDA | 41,921 | 7,412 | 4,711 | | 98 | 798 | 54,940 |
| GEORGIA | 15,769 | 6,911 | 4,354 | | 490 | 196 | 27,720 |
| HAWAII | 963 | 196 | 1,470 | | | | 2,629 |
| IDAHO | | | | | | | 0 |
| ILLINOIS | 30,488 | 13,201 | 7,799 | 392 | 294 | 1,478 | 53,652 |
| INDIANA | 32,647 | 12,166 | 5,726 | 238 | 245 | 392 | 51,414 |
| IOWA | | 3,318 | 141 | 980 | 14 | | 4,453 |
| KANSAS | 132 | | 679 | 294 | | | 1,105 |
| KENTUCKY | 12,877 | 5,831 | 98 | | 147 | 175 | 19,128 |
| LOUISIANA | 6,530 | 2,140 | 2,625 | | | | 11,295 |
| MAINE | 4,140 | 22,842 | | | | | 26,982 |
| MARYLAND | 2,598 | 27,267 | 3,758 | 98 | 147 | 536 | 34,404 |
| MASSACHUSETTS | 3,773 | 38,984 | 2,914 | 3,073 | 2,082 | 21 | 50,847 |
| MICHIGAN | 20,237 | 27,456 | 882 | 4,265 | | | 52,840 |
| MINNESOTA | 5,537 | 33,074 | 35 | 490 | 147 | 1,055 | 40,338 |
| MISSISSIPPI | 6,480 | 769 | 49 | | | | 7,298 |
| MISSOURI | 24,122 | 3,360 | 3,555 | 2,591 | | | 33,628 |
| MONTANA | 441 | 294 | 98 | | 49 | | 882 |
| NEBRASKA | 10,755 | 2,040 | | | | | 12,795 |
| NEVADA | 9,400 | 4,428 | | | | | 13,828 |
| NEW HAMPSHIRE | 196 | 949 | 147 | | | 226 | 1,518 |
| NEW JERSEY | 9,596 | 18,128 | | | | 484 | 28,208 |
| NEW MEXICO | 10,685 | 196 | 147 | 98 | 49 | | 11,175 |
| NEW YORK | 12,789 | 61,930 | 4,221 | 2,606 | 2,576 | 327 | 84,449 |
| NORTH CAROLINA | 12,041 | 2,212 | 2,115 | | | 21 | 16,389 |
| NORTH DAKOTA | 98 | | | | | | 98 |
| OHIO | 31,194 | 12,076 | 2,655 | 3,670 | | 439 | 50,034 |
| OKLAHOMA | 16,354 | 1,505 | 2,520 | | | | 20,379 |
| OREGON | 2,298 | 5,037 | 1,666 | | 98 | 189 | 9,288 |
| PENNSYLVANIA | 21,725 | 30,759 | 4,277 | | 667 | 963 | 58,391 |
| SOUTH CAROLINA | 8,970 | 1,054 | | | | | 10,024 |
| SOUTH DAKOTA | | | | | | | 0 |
| TENNESSEE | 23,015 | 8,267 | 98 | | | | 31,381 |
| TEXAS | 90,441 | 61,265 | 7,539 | 22,239 | 245 | 1421 | 183,150 |
| UTAH | 24,394 | 6,667 | 3,724 | 224 | | | 35,009 |
| VIRGINIA | 9,983 | 4,465 | 398 | | | | 14,846 |
| WASHINGTON | 14,969 | 6,605 | 5,334 | | | 105 | 27,013 |
| WISCONSIN | 9,708 | 3,820 | 2,800 | 147 | 182 | | 16,657 |
| WYOMING | 15,253 | 3,504 | | | | | 18,757 |
| **TOTAL** | **763,463** | **839,175** | **189,114** | **102,097** | **17,945** | **16,814** | **1,928,608** |

# CALIFORNIA APPLE COMMISSION-UNITED STATES DOMESTIC SHIPMENTS 2008-2009

**(MEASURED IN 40 lb. BOXES)**

| STATE | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| ALABAMA | 17,805 | 10,038 | 3,914 | | | | 31,757 |
| ALASKA | 98 | | | | | | 98 |
| ARIZONA | 24,454 | 30,298 | 4,107 | 1,078 | | 24 | 59,961 |
| ARKANSAS | 6,475 | 525 | | | | | 7,000 |
| CALIFORNIA | 274,786 | 673,536 | 177,101 | 93,594 | 4,384 | 25,446 | 1,248,847 |
| COLORADO | 12,467 | 17,015 | 3,761 | 3,111 | 844 | 1,260 | 38,458 |
| CONNECTICUT | 196 | 2,707 | | | | | 2,903 |
| DIST. OF COLUMBIA | 98 | | | | | | 98 |
| FLORIDA | 47,269 | 21,400 | 1,081 | 98 | 234 | 3,263 | 73,345 |
| GEORGIA | 15,113 | 23,352 | 4,315 | | 147 | 735 | 43,662 |
| HAWAII | 1,116 | 677 | 2,709 | | | | 4,502 |
| IDAHO | 5,261 | 539 | 294 | | | | 6,094 |
| ILLINOIS | 21,029 | 34,519 | 3,986 | 343 | 98 | 2,298 | 62,273 |
| INDIANA | 15,385 | 18,390 | 2,816 | 1,260 | 84 | 1,957 | 39,892 |
| IOWA | 588 | 3,094 | | | | | 3,682 |
| KANSAS | 1,793 | 1,029 | 147 | 245 | | | 3,214 |
| KENTUCKY | 11,478 | 12,793 | 1,274 | 666 | | 310 | 26,521 |
| LOUISIANA | 5,026 | 4,782 | 875 | | | | 10,683 |
| MAINE | | 13,174 | | | | | 13,174 |
| MARYLAND | 9,307 | 44,072 | 735 | 1,323 | 196 | 49 | 55,682 |
| MASSACHUSETTS | 13,838 | 74,234 | 1,568 | 2,030 | | 247 | 91,917 |
| MICHIGAN | 35,521 | 67,219 | 8,872 | 9,342 | | | 120,954 |
| MINNESOTA | 7,742 | 30,086 | 787 | 1,666 | 28 | 2,464 | 42,773 |
| MISSISSIPPI | 7,868 | 4,646 | 98 | | | | 12612 |
| MISSOURI | 27,449 | 16,864 | 3,066 | 774 | 98 | | 48,251 |
| MONTANA | | 91 | | | | 49 | 140 |
| NEBRASKA | 5,605 | 3,525 | | | | | 9,130 |
| NEVADA | 49 | 3772 | 196 | | | | 4,017 |
| NEW HAMPSHIRE | 196 | 735 | | | 221 | 285 | 1,437 |
| NEW JERSEY | 11,738 | 46,759 | 441 | | 441 | 372 | 59,751 |
| NEW MEXICO | 7,450 | 2,742 | | | 186 | | 10,378 |
| NEW YORK | 11,631 | 84,835 | 2,033 | 2,295 | 285 | 758 | 101,837 |
| NORTH CAROLINA | 21,744 | 8,981 | 2,905 | | | | 33,630 |
| NORTH DAKOTA | | 49 | | | | | 49 |
| OHIO | 33,557 | 34,912 | 4914 | 6057 | 147 | 349 | 79,936 |
| OKLAHOMA | 10,081 | 3,379 | 935 | | | | 14,395 |
| OREGON | 8,598 | 9,562 | 2170 | 735 | 294 | 4,403 | 25,762 |
| PENNSYLVANIA | 18,972 | 32,776 | 977 | 294 | 441 | 859 | 54,319 |
| SOUTH CAROLINA | 4,345 | 4,896 | | | | | 9,241 |
| SOUTH DAKOTA | 98 | | | | | | 98 |
| TENNESSEE | 18,900 | 21,901 | | 1,022 | | | 41,823 |
| TEXAS | 98,687 | 130,521 | 11,938 | 27,833 | 245 | 2,759 | 27,1983 |
| UTAH | 14,046 | 11,734 | 3,798 | 2,205 | | | 31,783 |
| VIRGINIA | 13,701 | 10,329 | 882 | 147 | | | 25,059 |
| WASHINGTON | 20,675 | 26,060 | 2,597 | | | 471 | 49,803 |
| WISCONSIN | 11,926 | 5,619 | | | | | 17,545 |
| WYOMING | 8,355 | 3,960 | | | | | 12,315 |
| **TOTAL** | **882,516** | **1,552,127** | **255,292** | **156,118** | **8,373** | **48,358** | **2,902,784** |

# CALIFORNIA'S TOP 5 STATES
## (MEASURED IN BOXES)

| 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 Massachusetts | 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 Massachusetts | 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 |

| 2013 - 2014 | |
|---|---|
| 1 California | 969,932 |
| 2 Texas | 248,105 |
| 3 Washington | 59,851 |
| 4 Illinois | 53,648 |
| 5 Florida | 42,993 |

| 2014 - 2015 | |
|---|---|
| 1 California | 661,422 |
| 2 Texas | 195,680 |
| 3 Florida | 70,100 |
| 4 Pennsylvania | 64,343 |
| 5 New York | 57,448 |

| 2015 - 2016 | |
|---|---|
| 1 California | 612,547 |
| 2 Texas | 164,500 |
| 3 Florida | 73,892 |
| 4 Illinois | 73,031 |
| 5 Pennsylvania | 51,881 |

| 2016 - 2017 | |
|---|---|
| 1 California | 622,088 |
| 2 Texas | 132,264 |
| 3 Florida | 80,270 |
| 4 Arizona | 77,312 |
| 5 Minnesota | 76,823 |

| 2017 - 2018 | |
|---|---|
| 1 California | 979,097 |
| 2 Texas | 173,764 |
| 3 New Jersey | 126,970 |
| 4 Georgia | 119,646 |
| 5 Washington | 61,179 |

| 2018 - 2019 | |
|---|---|
| 1 California | 770,121.90 |
| 2 Texas | 142,131 |
| 3 Nevada | 87,539 |
| 4 Georgia | 31,571 |
| 5 Ohio | 28,302 |

# EXPORT TOTALS
# 2018-2019
## (MEASURED IN BOXES)

| COUNTRY | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | OTHER | TOTAL |
|---|---|---|---|---|---|---|
| CANADA | 25,997 | 24,830 | 13,959 | 196 | 3,584 | 68,566.00 |
| COLUMBIA | | 2,009 | | | | 2,009.00 |
| EL SALVADOR | 1,840 | | | | | 1,840.00 |
| MEXICO | 18,542 | 11,229 | | | | 29,681.00 |
| TAIWAN | | | 5,468 | | | 5,468.00 |
| TOTAL | 46,379 | 38,068 | 19,427 | 196 | 3,584 | 107,564 |

# EXPORT TOTALS
# 2017-2018
## (MEASURED IN BOXES)

| COUNTRY | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | OTHER | TOTAL |
|---|---|---|---|---|---|---|
| CANADA | 35,203.20 | 17,736.90 | 1,368 | 4,671 | 196 | **59,175.10** |
| MALAYSIA | 49 | | 49 | | | **98** |
| MEXICO | 427 | 7,593 | | | | **8,020.00** |
| PUERTO RICO | 294 | 245 | | | | **539** |
| THAILAND | 290 | | | | | **290** |
| **TOTAL** | **36,263.20** | **25,574.90** | **1,417** | **4,671** | **196** | **68,122.10** |

# EXPORT TOTALS
# 2016-2017
## (MEASURED IN BOXES)

| COUNTRY | GALA | GRANNY SMITH | FUJI | BRAEBURN | CRIPPS PINK | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| CANADA | 53,736 | 15,360 | 245 | 225 | 147 | 483 | 70,196 |
| MEXICO | 1,896 | 8,820 | | | | | 10,716 |
| TAIWAN | | | 5,552 | | | | 5,552 |
| TOTAL | 55,632 | 24,180 | 5,797 | 225 | 147 | 483 | 86,464 |

# EXPORT TOTALS
# 2015-2016
## (MEASURED IN BOXES)

| COUNTRY | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| CANADA | 34,166 | 9,394 | 549 | 133 | 546 | 196 | 44,984 |
| HONG KONG | | | | | | | |
| INDIA | | | | | | | |
| INDONESIA | | | | | | | |
| MALAYSIA | | | | | | | |
| MEXICO | 11,760 | 6,853 | | | | | 19,908 |
| PANAMA | 514 | 6,853 | 6,853.00 | | | | 661 |
| PUERTO RICO | | 6,853 | | | | | 49 |
| SRI LANKA | | | | | | | |
| TAIWAN | | | 6,853.00 | | | | 13,682 |
| THAILAND | | | | | | | |
| VIETNAM | | | | | | | |
| TOTAL | 46,440 | 17,689 | 14,280 | 133 | 546 | 196 | 79,284 |

# EXPORT TOTALS
# 2014-2015
## (MEASURED IN BOXES)

| COUNTRY | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | TOTAL |
|---|---|---|---|---|---|---|
| CANADA | 62,546 | 21,849 | 9,420 | 441 | 343 | 94,599 |
| HONG KONG | 882 | | | | | 882 |
| INDIA | | 950 | | | | 950 |
| INDONESIA | | 4,831 | | | | 4,831 |
| MALAYSIA | | 17,933 | | | | 17,933 |
| MEXICO | 6,762 | 4,389 | | | | 11,151 |
| PHILLIPPINES | | 3,910 | | | | 3,910 |
| PUERTO RICO | | 686 | | | | 686 |
| SRI LANKA | | 2,885 | | | | 2,885 |
| TAIWAN | | 2,940 | 25,912 | | | 28,852 |
| THAILAND | | 9,690 | | | | 9,690 |
| VIETNAM | | 980 | | | | 980 |
| TOTAL | 70,190 | 71,043 | 35,332 | 441 | 343 | 177,349 |

# EXPORT TOTALS
## 2013-2014
### (MEASURED IN BOXES)

| COUNTRY | GALA | GRANNY SMITH | FUJI | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|
| CANADA | 74,805 | 43,226 | 13,388 | 196 | 490 | 132,105 |
| ECUADOR | | 2,696 | | | | 2,696 |
| FRENCH POLYNESIA | 294 | | | | | 294 |
| INDONESIA | | 980 | | | | 980 |
| MALAYSIA | | 46,509 | | | | 46,509 |
| MEXICO | 199 | 30,985 | | | | 31,184 |
| PERU | | 931 | | | | 931 |
| PHILLIPPINES | | 6,860 | | | | 6,860 |
| PUERTO RICO | 49 | | | | | 49 |
| SINGAPORE | | 4,662 | | | | 4,662 |
| SRI LANKA | | 11,680 | | | | 11,680 |
| TAIWAN | 19 | 4,786 | 5,504 | | | 10,309 |
| THAILAND | | 7,825 | | | | 7,825 |
| UNITED ARAB EMIRATES | | 4,655 | | | | 4,655 |
| VIETNAM | | 3,900 | | | | 3,900 |
| TOTAL | 75,366 | 169,695 | 18,892 | 196 | 490 | 256,084 |

# EXPORT TOTALS
# 2012-2013
### (MEASURED IN BOXES)

| 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 | 931 | 309,197 | 309,197 |

# EXPORT TOTALS
# 2011-2012
## (MEASURED IN BOXES)

| 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 | | 7,791 | | | | | 7,791 |
| PERU | | 2,940 | | | | | 2,940 |
| PHILLIPINES | | 2,910 | | | | | 2,910 |
| SRI LANKA | | 5,880 | | | | | 5,880 |
| TAIWAN | | 0 | 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
## 2010-2011
### (MEASURED IN BOXES)

| 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 |
| PHILLIPINES | | 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 | 0 | 147 | 242,385 |

# EXPORT TOTALS
# 2009-2010
## (MEASURED IN BOXES)

| COUNTRY | GALA | GRANNY SMITH | FUJI | CRIPPS PINK | BRAEBURN | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| CANADA | 73,846 | 54,643 | 1,127 | 392 | | 119 | 130,127 |
| 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 |
| PHILLIPINES | | 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 | | | | | | |
| VIETNAM | | 980 | | | | | |
| TOTAL | 100,578 | 164,232 | 60,427 | 392 | 0 | 119 | 324,768 |

# EXPORT TOTALS
# 2008-2009
## (MEASURED IN BOXES)

| 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 | 0 | 906 | 643,851 |

# HISTORICAL PACK OUT REPORT
## (MEASURED IN BOXES)

| VARIETY | 2007/2008 | 2008/2009 | 2009/2010 | 2010/2011 | 2011/2012 | 2012/2013 | 2013/2014 | 2014/2015 | 2015-2016 | 2016-2017 | 2017-2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FUJI | 295,886<br>295,886 | 337,244<br>337,244 | 249,541<br>249,541 | 367,770.3<br>367,770.3 | 227,475<br>227,475 | 213,223<br>213,223 | 245,745 | 262,849.80 | 232,140.00 | 306,231.00 | 166,135.4 |
| GALA | 714,879<br>714,879 | 1,035,461<br>1,035,461 | 864,044<br>864,044 | 969,350.2<br>969,350.2 | 1,011,727<br>1,011,727 | 801,831<br>801,831 | 761,904 | 758,736.90 | 977,006.40 | 951,408.40 | 987,921.4 |
| GRANNY SMITH | 1,244,291<br>1,244,291 | 1,943,585<br>1,943,585 | 805,345<br>805,345 | 1,085,746<br>1,085,746 | 1,113,778<br>1,113,778 | 905,965<br>905,965 | 969,320 | 763,849.30 | 443,648.00 | 429,506.20 | 469,634.6 |
| CRIPPS PINK | 165,477<br>165,477 | 172,708<br>172,708 | 102,489<br>102,489 | 146,317.5<br>146,317.5 | 119,219<br>119,219 | 95,446<br>95,446 | 142,530 | 63,208.60 | 75,355.30 | 100,066.00 | 77,683.8 |
| BRAEBURN | 24,831<br>24,831 | 8,373<br>8,373 | 17,945<br>17,945 | 22,297.9<br>22,297.9 | 7,201<br>7,201 | 10,675<br>10,675 | 18,460 | 6,694.10 | 13,519.60 | 7,189.40 | 4,663 |
| ARKANSAS BLACK | | | | 6,796.4<br>6,796.4 | | | | | | | |
| GOLDEN DELICIOUS | | | 739<br>739 | 1,452<br>1,452 | | | | | 5.00 | | |
| GRAVESTEIN | | | | 8<br>8 | | | | | | | |
| HONEYCRISP | | | | 9,010.6<br>9,010.6 | | | 8,998 | 6,192.00 | | | |
| JONAGOLD | 492<br>492 | | | | | | | | | | |
| LADY APPLE | | | | 293.13<br>293.13 | | | | | | | |
| PIPPIN | | | | 274<br>274 | | | | | | | |
| RED DELICIOUS | 780<br>780 | | 678<br>678 | 512<br>512 | 639<br>639 | 671<br>671 | 2,015 | 2,778.00 | 1,366.00 | 2,547.00 | 1,842 |
| SPITZENBERG | | | | 180<br>180 | | | | | | | |
| SUNDOWNER | 1,177<br>1,177 | | | | | | | | | | 155 |
| SWEETIE | | | | | | | | 2,766.00 | | | |
| OTHER | 26,355<br>26,355 | 49,264<br>49,264 | 15,516<br>15,516 | 21,469<br>21,469 | 169,775<br>169,775 | 30,146<br>30,146 | 37,499 | 57,679.00 | 30,277.00 | 40,372.00 | 25,233 |
| | | | | | | | | | | | |
| **Total Packed** | **2,474,168** | **3,546,635** | **2,056,297** | **2,631,477** | **2,649,814** | **2,057,957** | **2,186,471** | **1,924,753.70** | **1,773,317.30** | **1,837,320.00** | **1,733,268.20** |
| **Total Shipped** | **2,474,168** | **3,546,635** | **2,056,297** | **2,631,477** | **2,649,814** | **2,057,957** | **2,186,471** | **1,924,753.70** | **1,769,710.30** | **1,837,320.00** | **1,733,268.20** |

# INDUSTRY COMMUNICATIONS

# APPLE COMMUNICATIONS

The California Apple Commission takes pride in ensuring our audience is kept up to date with issues concerning the apple industry. The Commission is on social media. Please follow us on the following social media outlets and let us know what you think. We would love to know what you want to hear more about.

Facebook.com/CaliforniaAppleCommission

Pinterest.com/calapple

The Commission has published a series of newsletters throughout the season, and they are included in this year's annual report. The Commission encourages you to sign up for our newsletters that are available both online and in hard copy. To sign up for the California Apple Commission's online newsletter, visit Calapple.org under the "About Us" tab. You can subscribe in the newsletter section. To subscribe to our hard copy newsletter please contact the Commission office. The Commission sends out newsletters on a bi-monthly basis.

CALIFORNIA APPLE COMMISSION

# Newsletter

Issue No. 129 July/August 2018

## COMMISSION MEETS WITH U.S. AGRICUTLURE SECRETARY, SONNY PERDUE

On August 14, 2018, the California Apple Commission met with U.S. Agriculture Secretary Sonny Perdue, along with local growers and producers in Modesto, Calif., at a town hall meeting to learn about critical agriculture issues facing Central Valley farmers. The topic of discussions included, water, trade barriers and upcoming tariffs.


## US & MEXICO REACH NEW TRADE AGREEMENT

The United States and Mexico reached an agreement to enter a new trade deal, replacing the former North American Free Trade Agreement (NAFTA). The new trade pact will be called “The United States - Mexico Trade Agreement,” according to President Trump. Mexico President Nieto stated that “This is something very positive for the United States and Mexico,” and, has agreed to immediately begin purchasing as many agricultural products from the United States as possible. For more information, please contact the Commission office.

## ASIA FRUIT LOGISTICA

On September 5-7, 2018 the California Apple Commission (CAC) in conjunction with the US Apple Export Council (USAEC) will travel to Hong Kong for Asia Fruit Logistica. This is the largest fresh fruit trade show in Asia and provides the Commission the opportunity to reach a vast audience and allows visitors to get in direct contact with exhibitors. The Asia Fruit Logistica in Hong Kong is Asia’s leading trade show for the international fresh fruit and vegetable business. The CAC would like to thank the USAEC and the Foreign Ag Service for helping fund this trip. For more information, please contact the Commission office.

## UNITED FRESH PUBLIC POLICY CONFERENCE

On September 24-26, 2018, the California Apple Commission staff will attend the United Washington Public Policy Conference. This conference is an annual event held in Washington DC, which provides the produce industry the opportunity to gather together and have a face to face dialogue with key members of Congress and address the industry’s most pressing public policy matters. If you would like more information, please contact the Commission office.

## PRODUCE MARKETING ASSOCIATION (PMA) FRESH SUMMIT

The Produce Marketing Association Fresh Summit’s annual convention and exposition, will take place October 18-20, 2018, at the Orange County Convention Center in Orlando, Florida. PMA helps members grow by providing connections that expand business opportunities and increase sales and consumption. In addition, PMA allows the Commission to meet and maintain relationships with other industry leaders as it connects with the industry on current industry topics and workshops. In 2019, PMA will be held in Anaheim, California. For more information, please contact the Commission office.

## CALIFORNIA APPLE MEXICO INSPECTOR

In mid-July, the Mexico inspector arrived in California to start the California/Mexico apple export program. In accordance with the California/Mexico work plan, the Mexico inspector must certify all packing sheds and fumigation chambers intending on exporting apples to Mexico. If you have any questions regarding the Mexico Export Program, please contact Elizabeth Carranza at the Commission office.

## CAC ANNUAL REPORT

In the near future, please be on the lookout for the California Apple Commission Annual Report. The Annual Report includes information on current and future research, education projects, market reports, and other pertinent industry information. If you would like a copy, please contact the Commission office or email us at calapple@calapple.org. Additionally, the Annual Report can be found on the CAC website at www.calapple.org/AnnualReport.

***Did you know you can receive an e-newsletter instead of the snail mail version? If you would like to sign up, please email intern@calapple.org*

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## APPLE BITES

### EASY SLOW-COOKER APPLE BUTTER

Ingredients:

1. 5 lbs. California apples, chopped
2. 1 cup packed light brown sugar
3. 2 teaspoons cinnamon
4. ½ teaspoon salt

Directions:

1. Wash, core and chop 5 pounds of California apples, leaving the peels on. To get a thicker butter in the shortest amount of time, chop smaller pieces.
2. Add the remaining ingredients to a 5-6 quart slow cooker and toss to mix.
3. Cover and cook apples on high for 4-5 hours, stirring occasionally, until soft and cooked through. When apples are completely soft, puree the apples with an immersion blender. Or carefully transfer the hot mixture in batches in a blender or food processer until completely smooth.
4. Continue cooking, partially covered, on high for 30-60 minutes more or until the apples butter has reduced to your desired thickness.

### CALENDAR OF EVENTS

- **Asia Fruit Logistica**

  -Date: September 4-7, 2018

  -Hong Kong, China
- **United Fresh Public Policy Conference**

  -Date: September 24-26, 2018

  - Washington, D.C
- **Produce Marketing Association (PMA)**

  -Date: October 18-20, 2018

  -Orlando, Florida

CALIFORNIA APPLE COMMISSION Newsletter
Issue No.130 September/October 2018

## CAC ATTENDS AG IN THE CLASSROOM CONFERENCE

As a member of the California Foundation for Agriculture in the Classroom, the CAC attended its first Ag. In the Classroom conference from September 27-29 in Palm Springs, CA. At this conference, the CAC had the opportunity to learn more about the program from organization leadership and California Department of Food and Agriculture secretary, Karen Ross. For any questions regarding the CAC's participation in this program or conference attendance, please do not hesitate to contact the Commission office.

## U.S., CANADA & MEXICO REACH NEWTRADE AGREEMENT

The United States, Mexico, and Canada have reached a new trade deal to replace NAFTA. The new deal is renamed The United States-Mexico-Canada Agreement (USMCA) and focuses mostly on the automobile industry, however, there are factors of U.S. agriculture. While the agricultural provisions in Canada are focused mainly on the dairy, beef, pork, and grain industries, a zero tariff agreement was reached on all agricultural products traded between the U.S. and Mexico. Some factors that benefit the entire agricultural industry in all 3 countries include: modern language to enhance information exchange in relation to ag. biotechnology trade issues; science-based phytosanitary measures; grading standards and services agreement; and notification of SPS issues within 5 days, as opposed to 7. This new proposed agreement, however, is still in need of approval from Congress, and the CAC will provide an update when the timeline for approval becomes clearer after the upcoming election.

## CA APPLE TAIWAN AUDIT

In late October, APHIS conducted the annual on-site inspection for U.S. apples to Taiwan. The inspection included on-site audits of supplying orchards and packinghouses planning to export apples to Taiwan. If you have any questions regarding the Taiwan Export Program, please contact Elizabeth Carranza at the Commission office.

## UNITED FRSH HOSTS LISTERIA CONFERENCE

In September, the CAC attended a 1.5 day intervention and control workshop on Listeria. The workshop was designed specifically for the produce industry and featured: a general session on sanitary design, sanitation best practices, and environmental monitoring with breakout sessions, panel discussions, case studies, and more. For more information regarding this workshop, please contact the Commission office.

## UNITED FRESH PUBLIC POLICY CONFERENCE

On September 24-26, 2018, the California Apple Commission staff attended the United Washington Public Policy Conference. This conference is an annual event held in Washington DC, which provides the produce industry the opportunity to gather together and have a face to face dialogue with key members of Congress and address the industry's most pressing public policy matters. For example, issues concerning labor, trade and tariffs, newly announced ATP funding, and the security of MAP funds in the upcoming 2018 Farm Bill were discussed. If you would like more information, please contact the Commission office.

## ASIA FRUIT LOGISTICA

On September 5-7, 2018, The California Apple Commission joined the U.S. Apple Export Council (USAEC) in Hong Kong for Asia Fruit Logistica. This is the largest fresh fruit trade show in Asia and provides the Commission the unique opportunity to reach a vast audience of consumers and buyers. Asia is a promising market for California apples, and the Commission provided information to buyers about the availability of California apples. The CAC would like to thank the FAS and USAEC for providing this opportunity. For additional information, please contact Elizabeth Carranza at the Commission office.

## COMMISSION ATTENDS PMA

On October 18-20, 2018, the California Apple Commission attended the Produce Marketing Association's Fresh Summit's (PMA) annual convention and exposition, held at the Orange County Convention Center in Orlando, Florida. PMA helps members grow by providing connections that expand business opportunities and increase sales and consumption. In addition, PMA allows the Commission to meet and maintain relationships with other industry leaders, as it connects with the industry on being updated on current industry topics and workshops. In 2019, PMA will be held in Anaheim, California. For more information, please contact the Commission office.

## CAC WELCOMES NEW INTERN

In September, we welcomed Nicole Helms as our newest intern. Nicole originates from Rio Oso and is attending CSU Fresno to pursue a degree in Agricultural Communications. Nicole enjoys spending time with her family and friends, being outdoors, adventuring, and has a passion for agriculture. She looks forward to the valuable knowledge that she will gain through this internship experience.

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## CAC MOVES OFFICE

We are excited to announce that the CAC office has moved. We are still located in the same office building, therefore, our address and telephone number remain the same with the exception of our Suite Number. Please make a note of our **New Suite Number #152**. We hope you will stop in and say hi if you are in the area.

### Cinnamon Roll Apple Pie Apple Bites

**Ingredients:**

1. 2 cans (17.5 oz.) refrigerated cinnamon rolls with icing
2. 3 California Granny Smith apples, thinly sliced
3. 1 pkg. (3.4 oz.) JELL-O Vanilla Flavor Instant Pudding

**Directions:**

1.Heat oven to 305°F.

2.Separate Cinnamon Rolls. Place 6 rolls in single layer on bottom of 9-inch pie plate sprayed with cooking spray; press to flatten and completely cover bottom and side of pie plate. Reserve remaining cinnamon rolls and icing for later use. Bake crust 10 min.

3.Toss apples with dry pudding mix and cinnamon; spoon into cinnamon roll crust.

4.Press remaining cinnamon rolls into 5-inch rounds. Place around outer rim of pie plate, leaving opening in center to allow steam to escape. Press edges of rolls together to cover filling and to seal edge of bottom crust.

5.Bake 40-45 min. or until apples are tender and crust is golden brown. Drizzle with reserved icing.

*Recipe courtesy of* www.Kraftrecipes.com/recipes/cinnamon-roll-apple-pie.

## CALENDAR OF EVENTS

- November 14-15-USAEDC (U.S. Agricultural Export Development Council) Conference- Baltimore, MD
- December TBA- CAC Board Meeting
- January 2019- U.S. Apple Meetings- Washington, D.C.
- February 6-8 2019- Fruit Logistica- Berlin, Germany
- February 13-15- US Apple Association Government Affairs Committee Meeting

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CALIFORNIA APPLE COMMISSION

*Wishing you a Merry Christmas, and Happy New Year from the CAC!*

# Newsletter

Issue No. 132 November/December 2018

## CALIFORNIA APPLE COMMISSION CONTINUATION HEARING

The California Department of Food and Agriculture (CDFA) has set the Public Hearing for the Continuation of the California Apple Commission for Wednesday, January 16, 2019. The continuation referendum will be held at the Robert J Cabral Agriculture Center, 2101 E Earhart Ave., Stockton, CA, beginning at 10:00 AM in the Delta classroom. The State of California Department of Food and Agriculture is required under the Commission Law to conduct a hearing every five years to determine whether the operation of the Commission should be continued. All California apple producers and other interested persons are invited to participate in this hearing.

## AGRICULTURAL LEADERSHIP OPPORTUNITY

The California Apple Commission, and several other agricultural groups based in the San Joaquin Valley, have joined with West Hills College Lemoore, to launch a valley-wide ag leadership initiative to foster the next generation of leaders. The course will be launched on January 23, 2019. The program will be available to all community college students in the region. Students will produce reports on significant issues affecting agriculture and meet weekly with agricultural leaders in a classroom setting, and culminates with a trip to Sacramento where the students will interact with legislators, gubernatorial appointees and consultants. For more information on this opportunity, please contact the Commission.

## E-DISCLOSURE FOR E-FILING FORM 700 REMINDER

As outlined by CDFA and the Fair Political Practices Commission (FPPC) all Board of Directors filers must complete the necessary Form 700. Board members are now eligible to submit your Form 700 electronically through eDisclosure. To access eDisclosure system and complete your e-filing Form 700, please log on to **https://form700.fppc.ca.gov/**. Upon login you will see a list of positions that you are required to file a Form 700 for. Once completed, your Form will be saved in your online-filing cabinet under "Previous Filings" menu. **As a reminder, the Form 700 is due April 2, 2019.** Should you have any problems accessing or completing your eDisclosure Form 700 please contact your assigned FPPC filing officer, Christine Chen at (916) 324-7602 or via email at Form700@fppc.ca.gov. As always, the Commission can help you file your Form 700. Please contact the CAC office for assistance.

## CAC ATTENDS U.S. AGRICULTURAL EXPORT DEVELOPMENT CONFERENCE

Members from the California Apple Commission staff recently attended the U.S. Agricultural Export Development (USAEDC) Conference from November 14-15th in Baltimore, Maryland. This two day annual conference features many informational presentations regarding the current state of agricultural exports from the U.S. High-ranking members from the Foreign Agricultural Service (FAS) and representatives from various Agricultural Trade Office (ATO) international posts were in attendance. A main focus of this year's conference was the current state of ongoing trade wars, tariffs, and a new funding program FAS has made available to offset some of these barriers. This program, commonly known as the Agricultural Trade Promotion Program (ATPP), was designed to help U.S. agricultural exporters develop new markets despite the adverse effects of other countries' tariff and non-tariff barriers. A total of $200 million in funding is available, and the CAC has taken advantage of this opportunity via the U.S. Apple Export Council. Funding decisions are expected to be announced sometime in January, and the Commission will provide updates as they become available.

## H-2A PROGRAM ADVERSE EFFECT WAGE RATE UPDATE

The National Council of Agricultural Employers (NCAE), met to discuss the 2019 Adverse Effect Wage Rate (AEWR) for the H-2A program. The H-2A program allows U.S. employers or U.S. agents who meet specific regulatory requirements to bring foreign nationals to the United States to fill temporary agricultural jobs. On December 26, 2018, the new AEWR were published. Accordingly, the 2019 Adverse Effect Wage Rate (AEWR) proposed for California, will be paid $13.92 per hour, for agricultural work performed by H-2A program, and U.S. workers, effective January 9, 2019.

## FARM BILL PASSES

The 2018 Farm Bill was passed by both the Senate and House of Representatives and signed by President Trump on December 20, 2018. It covers most federal government policies related to agriculture in the United States. The Farm Bill comes up for renewal every five years. Many individuals and organizations contribute to the Farm Bill, including members of government and special interest groups. The legislation included a variety of federal grant programs, funding for farmers market and local food programs.

## CAC TO ATTEND FRUIT LOGISTICA IN BERLIN

On February 6-8, 2019, the California Apple Commission (CAC) will travel to Berlin, Germany for Fruit Logistica. This is the largest fresh fruit trade show in the world, it covers the fresh produce business and offers a complete picture of the latest innovations, products, and services in the international supply chain. The trade show provides the Commission the unique opportunity to reach a vast audience of retailers and importers both around the world. For more information, please contact the Commission office.

## 2018 MEXICO INSPECTOR PROGRAM CONCLUSION

In mid-July, the Mexico inspector arrived in California to start the California/Mexico apple export program. In accordance with the California/Mexico work plan, the Mexico inspector must certify all packing sheds and fumigation chambers intending on exporting apples to Mexico. If you have any questions regarding the Mexico Export Program, please contact Elizabeth Carranza at the Commission office.

## ELECTION RESULTS: CALIFORNIA LEADERSHIP CHANGES

As anticipated, the 2018 mid-term election resulted in many significant transitions for the State of California and the U.S. as a whole. The greatest transition was seen in the House of Representatives shift in majority to the Democratic Party with a count of 199 Republicans to 235 Democrats. In California, the Republicans did not pick up any additional seats, but lost a total of 7. Two of these seats were Central Valley Representatives, David Valadao and Jeff Denham, with whom CAC staff have developed long-term relationships. However, despite these losses, the CAC will strive to develop the same level of interaction with new House members. With regard to California state election results, former Lieutenant Governor, Gavin Newsom, was elected Governor, Eleni Kounalakis was elected Lieutenant Governor, and former Congressman Xavier Becerra was elected Attorney General. Governor Newsom has not yet appointed a Secretary of Agriculture, however, the CAC will continue to update the industry with any new developments.

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## APPLE BITES

### Apple & Sunflower Seed Salad

2 California Granny Smith apples-cored and cubed
½ cup sunflower seeds
1 head romaine lettuce – chopped
1 dill pickle diced
2 tomatoes diced
Ranch dressing of your choice

In a large bowl, mix together the apples, sunflower seeds, lettuce, pickles and tomatoes. Pour dressing on top, toss and enjoy. *Recipe courtesy of www.allrecipes.com*

## CALENDAR OF EVENTS

- **Fruit Logistica**
  -Date: February 6-8, 2019
  -Location: Berlin, Germany
- **US Apple Association Government Affairs Meeting**
  -Date: February 13-14, 2018
  -Location: Washington, DC
- **US Apple Export Council Middle East Trade Mission**
  -Date: February 2018
  -Location: Dubai & Saudi Arabia
- **ANTAD Mexico**
  -Date: March 5-7, 2019
  -Location: Guadalajara, Mexico

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CALIFORNIA APPLE COMMISSION

# Newsletter

Issue No. 133 January/February 2019

## COMMISSION ATTENDS US APPLE GOVERNMENT AFFAIRS MEETING

On February 14, 2019, The US Apple Government Affairs Committee, Board of Directors, and State apple executives met on Capitol Hill in Washington, D.C. At this meeting, the Committee discussed the US Apple industry's official position on important topics including: immigration, food safety, trade, labor, and pesticide policies, among others. The Committee was also informed of an upcoming meeting between US Apple representatives and White House personnel to discuss trade issues, specifically including: the ratification of the USMCA agreement between the US, Mexico, and Canada; and the retaliatory tariffs imposed by Mexico, India, and China. US Apple serves the interests of the nation's apple growers on a wide range of issues including agricultural labor, export promotion, specialty crop farm bill programs, and federal nutrition programs. For more information regarding US Apple or this meeting, please contact the Commission office.

## COMMISSION APPLIES FOR SPECIALTY CROP BLOCK GRANT

The Commission has submitted one proposal for the Specialty Crop Block Grant program through the California Department of Agriculture, titled "Orchard floor management strategies to improve agroecosystem health for California apples." The Commission is happy to report that this proposal was invited back to Phase 2. If funded, the grant program would begin in November 2019. The CDFA SCBG review committee will make a final decision and announce funding results later in spring 2019. The Commission will provide updates as they are received. For any questions regarding these grant proposals, please contact the CAC office.

## COMMISSION ATTENDS FRUIT LOGISTICA

On February 2-8, 2019, the California Apple Commission participated in the Fruit Logistica trade show, located in Berlin, Germany, through the U.S. Apple Export Council. Fruit Logistica is the largest fresh fruits show in the world. It covers the fresh produce business and offers a complete picture of the latest innovations, projects, and services in the international supply chain. This trade show provides the Commission with the unique opportunity to reach a vast audience of retailers and importers from around the world. If you would like more information and plan on attending next year, please contact the Commission office.

## eDISCLOSURE FOR e-FILING FORM 700 REMINDER

As outlined by CDFA and the Fair Political Practices Commission (FPPC), all Board of Directors must complete the necessary Form 700. Board members are now eligible to submit their Form 700s electronically through eDisclosure. To access the eDisclosure system and complete e-filing Form 700, please log on to https://form700.fppc.ca.gov/. Upon logging in, you will see a list of positions that you are required to file a Form 700 for. Once completed, your Form 700 will be save in your online-filing cabinet under "Previous Filings" menu. **As a reminder, the Form 700 is due April 2, 2019**. Should you have any problems accessing or completing your eDisclsoure Form700, please contact your assigned FPPS filing officer, Christine Chen at (916) 324-7602 or via email at Form700@fppc.ca.gov. As always, the Commission can help you file your Form 700. Please contact the Commission office for assistance.

## COMMISSION TO ATTEND CAPITOL HILL DAY

The California Apple Commission will be visiting Washington D.C. from March 11-15, 2019. The purpose of this visit is to attend the US Apple Association Board Meeting, and to meet with Congressional members to provide information on current problems facing the apple industry. Topics to be discussed will include labor, water, tariffs and export issues, among others. If you would like more information about the upcoming visit, please contact the Commission office.

**HEAT ILLNESS PREVENTION TRAINING** The Department of Industrial Relations, Cal/OSHA Consultation & Agricultural Organizations are hosting a free heat illness prevention training session. The training will be hosted on Friday, April 12, 2019 in both Spanish and English. The 10:00 a.m. to 12:00 p.m. session will be in Spanish, and the 1:30 p.m. to 3:30 p.m. session will be held in English. Upon completion, certificates will be distributed to attendees. If you have any questions, please contact the CAC office. The training will be held at:

C.P.D.E.S. Portuguese Hall
172 W. Jefferson Ave. Easton, CA 93706

## COMMISSION ATTENDS THE APHIS ADMINISTRATOR'S APPLE COMMODITY SECTOR MEETING

On February 14, 2019, the Commission participated in the APHIS Apple Commodity Sector Meeting held in Washington, DC at the U.S. Department of Agriculture. The Commission met with senior APHIS officials to provide updates on specific market access issues currently affecting California. In addition, APHIS provided updates on the current status of their top market access requests in an effort to keep the industry up to date. USDA Marketing and Regulatory Programs Undersecretary, Greg Ibach, also attended this meeting to provide further insight, in addition to gaining industry perspective. For more information regarding market access updates or this meeting, please do not hesitate to contact the Commission office.

## INTERN SELECTED FOR 2019 YAL PROGRAM

The CAC's intern, Nicole Helms, has been selected to participate in the 2019 US Apple Young Apple Leaders (YAL) program. Nicole will be spending March 12-15th in Washington, D.C. meeting with apple industry leaders and attending Congressional meetings on US Apple's Capitol Hill Day. The mission of YAL is to equip the next generation with an understanding of federal regulatory and legislative apple issues, and provide an opportunity to learn from peers and apple leaders around the country. *The YAL program sponsors cover all costs associated with participation.*

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## APPLE BITES

### Sautéed Apples

1/4 cup butter
4 large tart California apples- peeled, cored, and sliced 1/4 in thick
2 teaspoons cornstarch
1/2 cup cold water
1/2 cup brown sugar
1/2 teaspoon ground cinnamon

1. In a large skillet or saucepan, melt butter over medium heat; add apples. Cook, stirring constantly, until apples are almost tender, about 6-7 minutes.
2. Dissolve cornstarch in water; add to skillet. Stir in brown sugar and cinnamon. Boil for 2 minutes, stirring occasionally. Remove from heat and serve warm.

*Recipe courtesy of www.allrecipes.com*

### CALENDAR OF EVENTS

- **Trade Mission with US Apple Export Council**
  - –Date: February 28-March 6 2019
  - –Location: Middle East
- **ANTAD Mexico**
  - –Date: March 5-7, 2019
  - –Location: Guadalajara, Mexico
- **US Apple Export Council**
  - –Date: March 12, 2019
  - –Location: Washington, D.C.
- **US Apple Capitol Hill Day**
  - – Date: March 13, 2019
  - – Location: Washington, D.C

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CALIFORNIA APPLE COMMISSION

# Newsletter

Issue No. 134 March/April 2019

## COMMISSION MEETS WITH US APPLE EXPORT COUNCIL

On March 12, 2019, the CAC met with the US Apple Export Council to discuss current market access and USAEC funding. The USAEC is expected to receive approximately $1 million in funding which will be utilized throughout 7-10 markets. The USAEC assists the Commission and other U.S. apple producing states in obtaining Market Access Program (MAP) and Technical Assistance for Specialty Crop (TASC) dollars for foreign markets. California currently receives MAP dollars for inspectors and in-county representatives for Canada, Mexico, and Southeast Asia. The USAEC markets include: Canada, Central America, India, Mexico, Southeast Asia, the Middle East, and the United Kingdom.

## ANTAD TRADESHOW

From March 4-8, 2019, representatives from the Commission traveled to Guadalajara, Mexico, to conduct market visits, meet with key retailers, importers, and distributors, and attend the annual Expo ANTAD. This year's event featured over 25,000 visitors and nearly 2,300 exhibitors. The event is aimed at the retail sector and features opportunities for the entire food industry. The Commission participated in meetings to establish new relationships and explore new business opportunities for the California apple industry. The CAC also had the opportunity to speak with USDA Undersecretary of Agriculture for Trade and Foreign Agriculture Affairs, Ted McKinney. Please contact the Commission office for more information.

## CDFA FUNDED RESEARCH PROJECTS SEEKS CA APPLE INDUSTRY GROWER PARTICIPANTS

This CDFA-funded project titled, "Novel field-based diagnostic strategies for management of powdery mildew in California specialty crops," will look at fungicide resistance in apple powdery mildew. The CDFA is looking to identify 6-10 locations where they can sample isolates early and late season. These samples will be used to identify and develop diagnostic markers for fungicide resistance. If you are interested in participating in this study, please contact the Commission office.

## COMMISSION ATTENDS CAPITOL HILL DAY

**Executive Director, Todd Sanders, Jessa Allen (US Apple), Jeff Colombini (Board Member), Congressman McNerney, Director of Trade and Technical Affairs, Elizabeth Carranza and Intern, Nicole Helms on US Apple's Capitol Hill Day**

On March 13, 2019, the Commission visited Washington, D.C. The purpose of these meetings was to attend the U.S. Apple Association Board meeting, and to meet with key Congressional members to provide information on current problems that face the California apple industry. Issues discussed were reforming labor laws, the United States-Mexico-Canada Trade Agreement, and additional funding for post harvest research for the USDA Agriculture Research Service (ARS). For more information on this visit, please contact the Commission office.

## GENEVA ROOTSTOCK

In March, the Commission had the opportunity to meet with Apple Rootstock Breeder and Geneticist, Dr. Gennaro Fazio, from USDA ARS based at Cornell University. Dr. Fazio presented industry members with information regarding the types of Geneva rootstocks that may be suitable for California's unique climate in its apple growing regions. On behalf of the Apple Rootstock Breeding Program, Dr. Fazio has agreed to partner with several industry members in Geneva rootstock trials beginning in 2020. For more information on these trials and Geneva rootstocks in general, please do not hesitate to contact the Commission office.

## UPCOMING CA APPLE ELECTIONS

The California Apple Commission will host district meeting conference calls to nominate its candidates for the 2019–2020 Board of Directors. All district meeting conference calls will be on May 7, 2019, at the Apple Commission office via Zoom Meeting at https://zoom.us/j/197497860 or by Conference Call at 1 (669) 900- 6833 - Meeting ID: 197 497 860. District 1 will begin at 10:00 a.m., District 2 will begin at 10:30 a.m., and District 3 will begin at 11:00 a.m. An election notice was mailed to all California growers. Please contact the CAC with any questions.

## APPLE GROWER OF THE YEAR NOMINATIONS

It's that time of year again where Apple Grower of the Year nominations are due. This year, the Commission would like to nominate Lawrence Sambado of Prima Frutta Packing. Mr. Sambado has been a California apple grower for many years, and is a continuous supporter of the California apple industry. To help Mr. Sambado be elected, you can nominate him at https://www.growingproduce.com/fruits/apple-grower-of-the-year/help-us-find-the-2019-apple-grower-of-the-year/. For more information, please contact the Commission office.

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## SEXUAL HARRASMENT PREVENTION TRAINING

There is an upcoming no-cost sexual harassment prevention training to be held on Friday, May 10, 2019, in both Spanish and English. The 10:00 a.m. to 12:00 p.m. session will be in Spanish, and the 1:30 p.m. to 3:30 p.m. session will be held in English. Each attendee will be given a certificate upon completion. To RSVP, call (559) 251-8468 or email clehn@niseifarmersleague.com.
The training is located at:

Tulare County Ag Commissioner's Auditorium
4437 S Laspina. Tulare, CA 93274

### APPLE BITES
### Apple Coleslaw

**Ingredients:**

- 3 cups chopped cabbage
- 1 unpeeled California red apple, cored and chopped
- 1 unpeeled California Granny Smith apples, cored and chopped
- 1 carrot, grated
- ½ cup finely chopped red bell pepper
- 2 green onions, finely chopped
- 1/3 cup mayonnaise
- 1/3 cup brown sugar
- 1 tablespoon lemon juice

**Directions:**

- In a large bowl, combine cabbage, red apple, green apple, carrot, red bell pepper, and green onions. In a small bowl, mix together mayonnaise, brown sugar, and lemon juice. Pour dressing over salad.

*Recipe courtesy of www.allrecipes.com*

### CALENDAR OF EVENTS

- United Fresh Produce Association
  - Date: June 10-12, 2019
  - Chicago, Illinois
- CAC Board of Directors Meeting
  - Date: TBD (June 2019)
- USAEDC
  - Date: July 2019
  - Baltimore, Maryland

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