UNIVERSITY OF CALIFORNIA, DAVIS
INTERNAL AUDIT SERVICES

College of Agricultural and Environmental Sciences
Plant Breeding Program - Strawberry Breeding
Internal Audit Services Project #14-75

December 2014

Fieldwork Performed by:

Tony Firpo, Principal Auditor
Victoria Owens, Principal Auditor
Nirali Patel, Principal Auditor
Anya Vassilieva, Principal Auditor
Sherrill Jenkins, Principal Auditor

Reviewed by:

Leslyn Kraus, Associate Director

Approved by:

Jeremiah J. Maher, Director

TABLE OF CONTENTS

College of Agricultural and Environmental Sciences
Plant Breeding Program - Strawberry Breeding
Internal Audit Services Project #14-75

MANAGEMENT SUMMARY

BACKGROUND

At the request of University of California Davis (UC Davis) Campus Counsel, Internal Audit Services conducted a review of UC Davis' Strawberry Breeding Program (SBP).

California is the nation's leading producer of strawberries. In 2013, over 2.3 billion pounds of strawberries were harvested in California, comprising approximately 88% of the fresh and frozen strawberries in the United States.[1] According to the California Department of Food and Agriculture (CDFA), strawberries are one of California's top 20 crop and livestock commodities.[2] University of California (UC) produced varieties make up an estimated 80% of California's strawberry production.[3]

UC Davis' SBP began in the 1930s and has continued to the present day. The SBP has been responsible for the release of a number of notable strawberry varieties, with over 30 patented varieties developed in the last six decades[4].

The SBP's success has been facilitated through the collaboration of individuals and groups from UC Davis, UC Office of the President (UCOP), UC Division of Agriculture and Natural Resources (ANR), as well as groups external to the University.

Breeders – Until their retirement in November 2014, there were two strawberry breeders (breeders) dedicated to the SBP. Both were faculty members in the UC Davis Department of Plant Sciences (Plant Sciences) within the College of Agricultural and Environmental Sciences (CA&ES). The breeders were responsible for developing the strawberry varieties that are the foundation of the SBP and receive a share of the SBP royalty revenues as explained in detail in the body of this report.

Plant Variety Release Committee (PVRC) – The PVRC is made up of faculty members in Plant Sciences, and until November, one of the breeders served as the committee chairperson. Standard practice is for breeders to complete a new variety release information packet including the Record of Invention (ROI) and submit it to the PVRC. The PVRC reviews the information and provides a recommendation to the Plant Sciences Chair regarding whether to proceed with the patent and release of the new variety.

Plant Sciences – Plant Sciences Department provides administrative support for the breeders, and coordinates the process of obtaining approval for the release through the PVRC. The Plant Sciences Chair must approve the request for variety release before it is sent to the Dean of the CA&ES. Plant Sciences also operates the greenhouse where UC Davis' copies of the strawberry varieties are maintained. A portion of the SBP royalty revenue is allocated to Plant Sciences.

[1] California Strawberry Commission, http://www.californiastrawberries.com/about_strawberries#
[2] California Agricultural Statistics Review, 2013-2014, http://www.cdfa.ca.gov/Statistics/PDFs/ResourceDirectory_2013-2014.pdf
[3] UC Division of Agriculture and Natural Resources, http://ucanr.edu/delivers/?impact=642
[4] UC Davis Strawberry Facts, http://news.ucdavis.edu/special_reports/strawberry-breeding/

College of Agricultural and Environmental Sciences– The Plant Sciences Department is based in the CA&ES. The CA&ES Dean is also the final approval authority for the release of a new strawberry variety before the variety release information packet is sent to Innovation*Access*. A portion of the SBP royalty revenue is allocated to the CA&ES.

Innovation*Access* – Innovation*Access* is a unit of the UC Davis Office of Research, and plays a key role in the SBP. Innovation*Access* has a section devoted to strawberry licensing, the Strawberry Licensing Program. This program:

- Receives and reviews the approved variety release information packet, and enters the data into the UCOP Patent Tracking System;
- Manages and directs patent filing and prosecution in conjunction with Innovation Alliances and Services at UCOP (see below);
- Ensures that the breeders have provided an Assignment of Rights to the University for the strawberry variety being patented;
- Negotiates licensing agreements on behalf of the University;
- Manages the records of master licensees in the Plant Tracking System, and approves sales to licensees in the Plant Tracking System; and,
- Manages test agreements between the SBP and test growers.

Plant Licensing Field Representative (Field Representative) – The Field Representative is part of the Strawberry Licensing Program, and is charged with visiting SBP test fields, licensees and growers to market UC Davis varieties, monitor their use, and provide horticultural expertise.

Innovation Alliances and Services – Located at UCOP and plays a key role in the SBP:

- Tracks the progress of patent prosecution based on input from Innovation*Access* and external law firms;
- Receives and records licensing fees and royalty payments in the Patent Tracking System; and,
- Calculates and distributes licensing fees and royalties to UC Davis and the breeders. Strawberry and other plant patent licensing fees and royalties are combined for the distribution to UC Davis.

Foundation Plant Services (FPS) – FPS maintains a collection of the current UC Davis patented strawberry varieties which are tested annually for disease. FPS also tests and creates disease-free copies of the advanced selections produced by the UC Davis breeders to ensure smooth distribution of clean stock when new varieties are released.

Licensees – In the United States, licensees are nurseries which propagate strawberry plants for sale to growers. In foreign countries, master licensees coordinate the granting of sub-licenses to nurseries that propagate the plants for sale. The licensees and master licensees collect grower royalties and remit them to Innovation Alliances and Services at UCOP.

Growers – The growers produce the strawberries that are ultimately sold to consumers.

California Strawberry Commission (CSC) – The CSC is a state-chartered agency of the California Department of Food and Agriculture established by the California State Legislature in 1993. The CSC represents nearly 600 strawberry shippers, processors and growers within the state of California and is funded by assessments of California strawberry growers.

Strawberry royalties have been trending upward over the past five years. During fiscal year (FY) 2012-2013, UC collected over $7.5 million in gross strawberry licensing fees and royalties from UC Davis varieties. Of this total, over $4.5 million was distributed to UC Davis after payments to inventors and deductions at the UCOP level. The latter is primarily for legal expenses and other direct expenses related to the SBP.

The SBP is currently at a crossroads with the retirement of the breeders who have been the driving force behind the SBP over the last few decades. UC Davis has a unique opportunity to re-envision the SBP, taking advantage of existing best practices and seizing opportunities for improvement as outlined in this report.

The people we spoke with during this review used several different designations for the strawberries. For simplicity, we will use "variety" or "selection" to mean a particular type of strawberry and "germplasm collection" to mean the entire collection of UC Davis strawberry varieties. The varieties in the collection each have a distinct genetic makeup, or "genotype". A glossary with these terms and others follows this report as Attachment VI.

PURPOSE AND SCOPE

In April 2014, the UC Davis Chancellor responded to a letter from a California State Assembly Member that raised questions and concerns regarding the SBP. Included in the Chancellor's response was a commitment to perform a programmatic and financial review of the SBP. Our review was conducted to fulfill that commitment.

The objective of our review was to assess internal controls of the SBP in the following areas:

- Recordkeeping and financial reporting;
- Licensing fees and royalty revenue;
- Safeguarding of plants and related intellectual property; and,
- Structure and mission of the SBP.

In order to conduct our review we performed the following procedures:

- Interviewed individuals from the groups listed in the preceding "Background" section of this report, with the exception of personnel from the California Strawberry Commission;
- Reviewed relevant UC Davis and UCOP policies and procedures;
- Visited locations where the strawberry collection is housed, and the FPS facility;
- Examined and tested supporting documentation to the extent considered necessary.

UC Davis also engaged an outside expert in plant breeding from Cornell University to conduct a programmatic review of the SBP. The results of that review are incorporated into this report.

Our review assessed current policies, procedures and practices of the SBP. Because royalties and licensing fees received by UCOP in one year are transmitted to UC Davis in the following year, our examination of SBP licensing fees and royalties covered revenues received by UCOP in FY 2011-2012 and distributed to UC Davis in FY 2012-2013. Although we audited revenues received by UCOP in FY 2011-2012, the financial Exhibits included in this report cover revenues received over the nine-year period from FY 2004-2005 through FY 2012-2013. The Exhibits in this report are revised versions of reports originally prepared by UC Davis management and CA&ES; for the fiscal years that were not audited, we adjusted the financial data in the original schedules to account for the inaccuracies and omissions that we identified for the fiscal year that was audited (as explained in the body of this report).

CONCLUSIONS

Following are our summary conclusions for each of the four objectives of the review.

Record keeping and financial reporting

In the university's accounting system, the SBP is not a distinct financial entity/organization separate from the faculty accounts of the breeders; as a result, now that the breeders have retired, the CA&ES and Plant Sciences will need to make decisions about the future financial structure and funding of the SBP under the next breeder/geneticist.

Regarding record keeping and financial reporting, we examined the SBP financial schedules that were provided to the California Legislature in April 2014, and identified inaccuracies and omissions. However, the cumulative net effect of these inaccuracies and omissions over the nine-year period presented is approximately $5,000, which is not considered to be significant. We revised the schedules, which are included as Exhibits to this report.

Licensing fees and royalty revenue

Regarding licensing fees and royalty revenues, we examined the internal controls surrounding the collection, processing and accounting for licensing fees and royalty revenues and distributions thereof, as well as use of such funds by UC Davis, and found no weaknesses with the exception of the following: licensees self-report sales data and remit royalties to UCOP semi-annually, but neither UCOP nor UC Davis engages professional auditors to audit the sales data and associated royalty payments for accuracy and completeness.

Safeguarding of plants and related intellectual property

We concluded that, in general, the SBP has operated with limited oversight, allowing the former breeders to take actions that could potentially conflict with the best interests of UC Davis and its constituents. These actions include barring the Plant Licensing Field Representative from monitoring strawberry growing fields owned or leased by UC Davis, and signing agreements on behalf of the Regents in violation of UC Delegation of Authority policy.

There are opportunities to enhance the protection of the intellectual property (IP) of the strawberry germplasm collection. For instance, the former breeders participated in the standard Field Day presentations which highlighted promising new strawberry selections before Innovation*Access* or other UC Davis units had information on the varieties that would enable them to evaluate the need to take steps to protect the University's IP rights. The breeders did not notify either Plant Sciences or Innovation*Access* of any potentially valuable selection until they chose to submit one to be considered for release. Additionally, under the program's usual practice, FPS does not genotype a plant until the decision has been made to seek a patent for that plant.

The information in the pedigree and performance database UC Davis has for the strawberry germplasm collection is incomplete. The database should include the complete lineage of the varieties in the collection, as well as data on the performance of the variety on tests of interest to nurseries and growers.

Practices were not sufficient to protect the physical security of the germplasm and the database from theft or loss. Since the audit, entry and exit controls at the greenhouse have been strengthened. Electronic security over the pedigree database could be improved.

Finally, we concluded that the process Innovation*Access* uses to oversee the SBP's international operations could be expanded. For example, it may be possible to increase automation by creating one database to manage shipments internationally and within the US. Additionally, the database used by Innovation*Access* to track international shipments was jointly created by and is under the contractual operation and control of the European master licensee, Eurosemillas, S.A. and may not be compliant with UCOP policy BFB-IS-3, *Electronic Information Security*.

Structure and mission of the SBP

The outside expert engaged to conduct the programmatic review of the SBP concluded as follows:

> "Overall, I determined that the program has been successful at the release of new cultivars of commercial importance, but has overlooked important breeding targets, outreach approaches and opportunities for mentoring of undergraduate and graduate students. Given the scope of the program and the resources available, I would expect a web site with detailed information on each variety released, a link to the relevant patents, and also research reports on each cultivar. There are many exciting future opportunities/challenges in genetics, genomics and breeding. Fruit quality traits should be a focus, as should incorporating better resistance to common pathogens and complexes, especially in light of fumigation changes. Fruit nutritional components and flavor components (such as volatiles) would be promising areas of exploration. Greater collaboration would enhance pathology, plant physiology and postharvest attributes and are strongly recommended for expansion."

A detailed discussion of our observations begins on the next page. The consultant's complete report on her programmatic review, "UC Davis Strawberry Breeding Program Review and Assessment" is attached to this report as Attachment VII.

Management Corrective Actions

CA&ES has developed an approach to address most of the recommendations included within this report. The approach involves the formation of a Campus Strawberry Workgroup for the SBP and the development of a remediation plan for the SBP. CA&ES has outlined its approach in the document, "Strawberry Breeding Program Remediation Plan," which is attached to this report as Attachment VIII. Management corrective actions that are not included within the attached document are included within the body of this report.

I. OBSERVATIONS, RECOMMENDATIONS, AND MANAGEMENT CORRECTIVE ACTIONS

A. RECORD KEEPING AND FINANCIAL REPORTING

1. In the university's accounting system, the SBP is not a distinct financial entity/organization separate from the faculty accounts of the breeders, which raises questions about the future financial structure of the SBP as the breeder eligible to become an emeritus faculty member retires.

Within the ledgers of the Plant Sciences department, each faculty member (including each of the breeders) has his/her own organization that includes, for example, all of the accounts for their extramurally-funded projects. The financial organizations of the breeders include the accounts in which the activities of the SBP are recorded; as such, the SBP is not a distinct financial entity separate from the breeders.

Breeder A, who is now an emeritus faculty member, indicated to Internal Audit Services that he may continue to do research after his retirement. (Internal Audit Services asked to meet with Breeder B, but he did not respond. Breeder B is not eligible for emeritus status.) The retirements of the breeders raise several questions including the following:

- As of June 30, 2014, the cumulative balances in the accounts of Breeders A and B were approximately $542,000 and $512,000, respectively. If Breeder A continues to do research at the university as an emeritus faculty member and claims a stake to some or all of the funds currently in his accounts, how will the SBP be funded under the next breeder/geneticist? (Plant Sciences has indicated that: (a) employees working on research under the direction of the breeders are continuing to be paid from the accounts of the breeders and therefore the accounts balances were drawn down somewhat by the retirement dates of the breeders; and (b) Plant Sciences policy for emeritus faculty is that they keep their funding so long as the funds are used for university business.)

- If the breeder(s) continue to conduct research after retirement, will they claim a stake to some or all of the future annual royalty revenues related to the varieties for which they are the inventors that, have historically flowed into their faculty accounts? (Plant Sciences has indicated that the funds will be directed to the new breeding program rather than the emeritus faculty.)

- When the next breeder/geneticist assumes control of the SBP, will the SBP become its own distinct financial entity in the accounting system or continue to be accounted for as it has been historically?

- If the SBP becomes its own financial entity and Breeder A continues active research as emeritus faculty, will the research activities of the breeders be included or excluded in the SBP?

- After his retirement, if Breeder A forms a privately-funded strawberry breeding company, competing with the UC Davis breeding program, and also continues his research as an emeritus faculty, how will UC Davis manage potential conflict of interest issues regarding their university research?

Recommendations

1. Regarding the cumulative balances currently in the accounts of the breeders, memorialize in writing arrangements between Plant Sciences and each of the breeders.
2. Regarding the department's share of the future annual royalty revenues for the breeders' varieties, Plant Sciences has indicated that the funds attributable to the SBP will flow to the accounts of the new breeding program rather than those of the emeritus breeders. As such, Plant Sciences should establish accounts for the new breeding program prior to the distribution of royalty revenues in FY15.
3. Regarding the future financial structure of the SBP, Plant Sciences should establish a distinct financial organization to account for the activities of the program. If a financial organization is established for the SBP, CA&ES and Plant Sciences will need to decide which funds, revenues, expenses, and activities will be accounted for in the accounts of the SBP vs. the accounts of the breeders, the accounts of the next breeder/geneticist, the accounts of the department, and the accounts of CA&ES.
4. In the past, there has been no annual financial reporting associated with the SBP. However, because of the lawsuit involving the CSC and UC Davis and the resulting publicity surrounding the program, CA&ES and Plant Sciences should prepare annual financial reports for the program in the future. Establishing a stand-alone financial organization for the SBP will assist in efficient and effective financial reporting.
5. Regarding Breeder A's potential conflict of interest between his privately-funded breeding company and his research as an emeritus faculty member, CA&ES and Plant Sciences should develop a plan and assign responsibility for managing the conflict.
6. Breeder A's company will likely take some portion of the SBP's typical market share, thereby reducing the royalty revenues that flow to the university, which will need to be taken into account when the university develops future budget projections for the strawberry breeding program.

Management Corrective Actions

a. Recommendations 1,3,4,5 and 6 are addressed in the remediation plan document from CA&ES management, Attachment VIII.

b. Regarding recommendation #2, in January 2015 Plant Sciences established an account for the FY15 strawberry breeding program royalty revenues. No further actions are necessary.

2. Internal Audit Services identified inaccuracies and omissions in the SBP financial schedules prepared by UC Davis for the California Legislature and therefore revised these schedules, which are attached to this report. The cumulative net effect of the inaccuracies and omissions over the nine-year period presented is approximately $5,000, which is not considered to be significant.

Background

In a letter dated March 6, 2014, The California Legislature (Legislature) wrote to the Chancellor with concerns surrounding the SBP; in a letter dated April 11, 2014, the Chancellor responded to the Legislature's letter. In the following section, the inquiries related to finances or revenues from the Legislature's letter are presented in bold, and the Chancellor's responses are included in quotes immediately below. (Note that UC Davis' response included four financial exhibits, which are referred to in the excerpts below.)

- **Program expenditures for the years 2005 through 2012**.
  "Please see Exhibit C ("UC Davis Plant Sciences Department Strawberry Program Revenue and Expenses.)"

- **Revenue generated by the Program for the years 2005 through 2012.**
  "Please see Exhibit A, which provides the amounts of revenue collected for the program and the amount distributed to UC Davis. Please also see Exhibit B, which shows the distribution of the revenue Davis received. I have also attached an Issue Report, dated May 2013, [not included in this Internal Audit Services report] that explains the methodology by which plant-patent revenue, including that for strawberries, is allocated at UC Davis."

- **Amount of revenue reinvested in strawberry research focused on developing pest and disease resistant strawberry varieties that would reduce use of fumigants.**
  "The SBP has not segregated its research, or its expenditures, specific to studies on pest and disease resistance for the purpose of reducing the use of fumigants. Rather, the program's breeding cycles focus on overall plant quality, which includes pest and disease resistance, including research on fungi traditionally addressed by fumigants, as well as many other characteristics such as taste, appearance, and fruit yield. Researchers in the CA&ES conduct research in the areas of pest and disease resistance in relation to the use of fumigants or alternatives and are funded by a variety of internal and external sources. All of these efforts rely on various funds of the CA&ES, which include revenues from the strawberry breeding program, but the CA&ES has not accounted for the funds provided specifically to fund sources other than what is stated in Exhibit A."

Internal Audit Services examined Exhibits A, B, and C and noted the observations listed below. Attachment IV to this report includes background information about the University of California's technology licensing program as well as definitions of some of the financial terms mentioned below. Also, Attachment V includes a chart diagramming the accounting for and flow of royalty funds at the UCOP and UC Davis levels.

Exhibit A

Two inaccuracies were noted in the original Exhibit A:

- **Research Shares**. The schedule included a column for "Research Shares" which was presented as a deduction from "Gross Strawberry Licensing Revenue" in calculating the total "Net to Davis" amount. Research share is in fact calculated by and accounted for at UCOP; however, these funds are distributed to UC Davis and therefore do not represent a deduction. The revised Exhibit A attached to this report does not show research share as a deduction.

- **Operating Charges**. Operating charges are assessed by UCOP to UC Davis for services provided by UCOP. [As explained in note (4) to the original schedule, "Starting in FY 2008-2009, the UCOP operating charges for strawberries and other plants were allocated based on what type of patent (utility patent or plant patent) was filed. UC Davis files plant patents for strawberry."] In the original schedule, 100% of the UCOP operating charges for all UC Davis plant patents were attributed to strawberries, which Internal Audit Services deemed to be inaccurate, resulting in operating charges being overstated. In the revised schedule, the UCOP operating charges attributable to strawberries have been allocated at approximately 90% each year, based on the ratio of gross revenues from strawberry patents compared to gross revenues for all plant patents. (In the chart immediately following this section, these amounts are included in the column entitled, "Add back of Operating Charges.)

Two omissions were also noted in the original Exhibit A:

- **Strawberry Portfolio Management Expenses**. These expenses represent salaries and benefits attributable to certain personnel at UC Davis who work in Innovation*Access* on the strawberry licensing program. Per a Memorandum of Understanding between UCOP and UC Davis, these expenses are treated as an operating charge to UC Davis from UCOP and, as such, represent a deduction in gross licensing revenues for purposes of calculating the amount distributed to UC Davis. Accordingly, the revised Exhibit A attached to this report includes a column for these expenses.

- **Operating Charges**. The original Exhibit A included operating charges from UCOP to UC Davis for fiscal years 2009 through 2013, but included no similar charges for fiscal years 2005 through 2008. As explained in note (4) to the original schedule:
  - "Prior to FY 2008-2009, operating costs were calculated without allocation based on patent types and, therefore, operating costs associated with strawberries cannot be reasonably estimated."

  Internal Audit Services evaluated the original schedule in light of this note and concluded that an estimate should be made of operating charges in fiscal years 2005 through 2008. Internal Audit Services worked with UCOP to establish a methodology based on (a) plant vs. utility allocations since UCOP began segregating these in FY 2009; and (b) gross revenue ratio for strawberry patents compared to gross revenues for all plant patents. The revised schedule includes an estimate of operating charges for the strawberry program for fiscal year 2004 through 2008.

The net effect of these inaccuracies and omissions is not significant as demonstrated by the table below, which summarizes the revisions by year and shows the cumulative effect of approximately $5,000 compared to the original schedule.

	Original Schedule - Net to Davis	Add-back of Research Shares	Add-back of Operating Charges	Deduct Strawberry Portfolio Management Expenses	Deduct FY 05-08 Operating Charges	Revised Net to Davis	Diffference
2004-05	$2,600,498	$28,976			($222,578)	$2,406,896	($193,602)
2005-06	$2,374,589	$75,772			($189,216)	$2,261,145	($113,444)
2006-07	$1,823,338	$72,561			($178,268)	$1,717,631	($105,707)
2007-08	$2,330,715	$114,508			($69,252)	$2,375,971	$45,256
2008-09	$2,470,540	$120,426	$14,939	($14,008)		$2,591,897	$121,357
2009-10	$3,674,768	$167,776	$26,643	($150,936)		$3,718,251	$43,483
2010-11	$3,931,537	$236,074	$5,512	($293,710)		$3,879,413	($52,124)
2011-12	$3,644,583	$307,790	$7,450	($188,848)		$3,770,975	$126,392
2012-13	$4,516,193	$323,726	$9,467	($199,601)		$4,649,785	$133,592
Cumulative	$27,366,761	$1,447,609	$64,011	($847,103)	($659,314)	$27,371,964	$5,203

Exhibit B

As the purpose of Exhibit B is to present the distribution of funds that UC Davis received, the "Total Distributed" amount for each year in the original schedule has been updated to reflect the changes noted above in the revised Exhibit A. Also, several inaccuracies were identified on the original Exhibit B:

Department of Plant Sciences: For each year, the schedule included an amount distributed for the "Strawberry Breeding Program" and an amount distributed for "Research and Educational Activities." Within Plant Sciences, the departmental policy for patent revenues distributed to the department is that 50% is allocated to the departmental account of the inventor and 50% is retained by the department for research and educational activities. As such, on Exhibit B, under the "Department of Plant Sciences" section, for each year, the amounts within the columns for "Strawberry Breeding Program" and "Research and Educational Activities" should be equal, i.e., 50% to the SBP and 50% to the department. On the original schedule, the amounts in the "Strawberry Breeding Program" column were correct; therefore, in the revised schedule, the amounts in the "Research and Educational Activities" column have been corrected to match those in the "Strawberry Breeding Program" column. The original schedule was incorrect because the SBP patent revenues attributable to the predecessors of the retired breeders (50% of which have continued to accrue to the SBP throughout the nine-year period presented) were inadvertently omitted from the calculations for the "Research and Educational Activities" column, thereby understating these amounts.

College of Agricultural & Environmental Sciences: On the original schedule, in the "College of Agricultural & Environmental Sciences" section, the amounts in the "Research and Educational Activities" column were incorrect. These figures have been corrected on the revised schedule.

Campuswide: Amounts in this column for each year are derived as the difference between the amount in the "Total Distributed" column and the sum of the amounts in the first four columns. Because the "Research and Educational Activities" columns included incorrect figures (as described in the points above), and the "Total Distributed" amounts were also incorrect as described previously regarding Exhibit A, the derived amounts in the "Campuswide Research and Educational Activities" column were also incorrect. These figures have been corrected on the revised schedule. Note that the "Total Distributed" amount for Exhibit B matches the "Net to Davis" total in Exhibit A and therefore was misstated by approximately $5,000 in the original schedule.

Exhibit C

For FY 2013, the original schedule omitted base funds of $299,034 which were allocated to the program by the CA&ES. This amount should have appeared in the column entitled, "UCD College of Ag & Env Sci." The revised schedule, which has been reformatted to fit onto one page, includes this base fund allocation.

Recommendation

No recommendation is considered necessary, since the revised Exhibits have been attached to this report (see Attachments I - III).

B. LICENSING FEES AND ROYALTY REVENUE

Licensees report sales data and remit royalties to UCOP semi-annually, but the university does not audit the sales data and associated royalty payments for accuracy and completeness.

On a semi-annual basis, UCOP notifies licensees of the requirement to submit royalty reports and remit royalty payments. Using a standard reporting template, licensees self-report to UCOP their sales data, which is submitted with the royalty payment. UCOP then reviews the royalty reports and processes the payments via the UCOP Patent Tracking System. UC Davis Innovation*Access* receives copies of the report for its review. The internal control processes at UCOP and UC Davis that we reviewed regarding royalty accounting and distributions are considered acceptable. However, the university does not engage professional auditors to conduct on-site audits at licensee businesses to determine whether the sales data being self-reported is accurate and complete. The university's licensee agreements include a right-to-audit clause, yet no audits of strawberry licensees have been conducted in many years.

Recommendation

1. Management should perform a cost/benefit analysis to determine if a licensee auditing program would be advantageous. Issues to be considered include:

    - Establishing the scope of the program, including perhaps an initial pilot program;
    - Identifying a funding source for the audits;
    - Assessing the likelihood that audits could be self-funded eventually by identifying under-reporting of licensee sales; and
    - Evaluating the potential impact on the university's relationships with licensees and other stakeholders.

Management Corrective Actions

a. Innovation*Access* management will perform the specified cost/benefit analysis, including consideration of the specified issues by February 15, 2016.

C. PROTECTION OF PHYSICAL AND INTELLECTUAL PROPERTY

Following are our observations on the systems and controls UC Davis has in place to protect its property in the SBP. We reviewed both the physical safeguards in place over the germplasm collection and research records, as well the legal protections in place for UC Davis' IP rights.

Our observations, combined with those of the consultant (See Attachment VII), indicate there are opportunities for improved oversight for both the SBP and the resulting germplasm and records, which are UC Davis' IP. In some cases, the breeders have been allowed to violate UC Davis policy and jeopardize UC Davis' rights despite the best intentions of the individuals involved.

Overall, we recommend UC Davis and CA&ES work together to develop a process for the oversight of the SBP, including the processes for negotiating and completing agreements with nurseries and growers, overseeing the variety release and patenting processes, and safeguarding the strawberry germplasm collection and records. The processes should have clearly defined roles and responsibilities and comply with all applicable policies and regulations.

Our individual observations are shown below.

1. The SBP has operated with limited oversight, allowing the breeders to take actions that could potentially conflict with the best interests of UC Davis and its constituents.

I. The position of Business Development and IP Manager (IP Manager) for the Strawberry Licensing Program has not exercised sufficient authority and may not have the necessary independence to effectively direct technology transfer activities for the SBP. This position manages a unit which is responsible for:

- Monitoring the patent application process for new varieties;
- Reviewing the royalty reports submitted by licensees for anomalies;
- Managing the records of Master Licensees in the Plant Tracking System;
- Negotiating with and approving new licensees;
- Marketing UC Davis varieties to licensees;
- Providing horticultural support to licensees; and
- Managing test agreements between the SBP and growers.

Most of these activities require the IP Manager to work closely with the breeders. The necessity of obtaining their cooperation, as well as the "service unit" orientation of Innovation*Access* resulted in a reticence by the IP manager to oppose the breeders. As a result, oversight was limited for the breeders' actions, including certain actions that disregarded policy.

II. In October of 2012, Breeder A told the Field Representative, an employee of Innovation*Access*, that he no longer wanted the Field Representative to visit any of his research sites (strawberry growing fields), including those owned or leased by UC Davis. The representative complied, believing that the ban was within Breeder A's rights as a full professor. Both the office of the Dean of CA&ES and the Strawberry Licensing Program were aware of the breeder's action. There was some communication with the Campus Counsel's Office regarding the situation, but it is unclear what action was taken as several of the individuals involved are no longer employed by UCD. The Field Representative's knowledge of activities in the test fields served as an important control to ensure all valuable selections were disclosed to Innovation*Access*. That control was lost with Breeder A's decision to bar the representative from the fields. The representative retired July 1, 2012 and subsequently came back as a contractor in September of 2012 limited by UC policy to 43% time, which also restricted the effectiveness of the position to provide oversight for the breeders' actions, support UC Davis' actions, and to encourage and monitor the licensees' use of UC Davis varieties. As of this date, the Field Representative has left, thus leaving this role unfilled.

Recommendation

1. The relationship between the Strawberry Licensing Program and the SBP breeder should be clarified. The roles, responsibilities and expectations of the two parties should comply with policy, be delineated to all involved, and enforced.
2. The Field Representative position should be filled and the position given sufficient authority and independence to be able to appropriately fulfill the assigned duties.

Management Corrective Actions

a. Innovation*Access* will work with CA&ES to clarify and document the relationship of Innovation*Access* with the new breeder including the roles, responsibilities and expectations of all parties by August 15, 2015.
b. The Field Representative position will be filled and the position given sufficient authority and independence to appropriately fulfill the assigned duties by August 15, 2015.

III. Test agreements, the agreements between the Regents and the growers propagating the program's advanced selections, were signed by Breeder A, although only the Executive Director and Associate Directors of the Innovation*Access* unit have signing authority. Historical practice allowed Breeder A to sign agreements with the growers, returning them to Innovation*Access* once complete. Breeder A stated he was never told by Innovation*Access* not to sign the test agreements, and since he developed the materials and the IP, he felt it was appropriate for him to talk to the growers about the test agreements. This practice violated UC Davis Delegation of Authority policy, and introduced the risk of the breeder appearing to obligate UC Davis and the Regents to agreements of which they had no knowledge.

Recommendation

1. Delegated Innovation*Access* personnel should execute and store all agreements related to the SBP, including test agreements.

Management Corrective Actions

a. By August 15, 2015, Innovation*Access* will work with the new breeder to ensure that all new and continuing test agreements and license agreements are negotiated, executed and stored by Innovation*Access*. This requirement will be included in the documentation of roles described above.

IV. The Plant Variety Release Committee (PVRC) is an important first control in the commercialization process. The committee reviews and approves all variety release information packets to ensure the selections put forward for a patent are unique and useful additions to the list of available varieties. The committee's membership consists of six faculty members from the Department of Plant Sciences. The committee does not have regularly scheduled meetings or agendas. Nor are any minutes or notes kept of its deliberations. The chair of the committee simply sends an email to the Plant Sciences Department Chair and signs the approval form. Breeder A was the chair of the PVRC, although another member called and ran the meeting if a strawberry selection was under consideration. Given the informality and small size of the committee, as well as the importance and visibility of the SBP, the breeder's status as chair might influence the PVRC's decision-making even when an alternate faculty member runs the meeting. Therefore, PVRC in this configuration cannot be considered an adequate control over the breeders' activities nor an effective advocate for UC Davis' interests.

Recommendation

1. Membership of the PVRC should be increased and include representatives from associated departments, such as Plant Pathology. Also, to better inform the CA&ES Dean about the committee, Plant Sciences should provide the Dean with a written document summarizing the operations of the PVRC and the membership of the PVRC, including a description as to how the committee chair is selected.

Management Corrective Actions

a. By August 15, 2015, Plant Sciences will provide the CA&ES Dean with a one-page description of the operations of the PVRC, including the membership and selection of the chair of the committee.

2. Pedigree information for the germplasm collection is incomplete.

Pedigree and performance data for the selections in the strawberry germplasm collection is an essential component of UC Davis' IP. The pedigree information in the custody of UC Davis is incomplete. The pedigrees in the database for the advanced - or "elite" - selections only go back to the parents of the selection and do not include the pedigrees for those parents. The database also does not contain any pedigree information for selections that are not categorized as elite, though some of these other selections may later be reclassified to elite. Further, the database has performance data for only a few elite selections, and that data is incomplete, as it does not have metrics for the selections' performance in all tests and against all common pathogens. On recent ROI forms, the breeders reference other notebooks as containing additional research data. UC Davis considers this additional information its property under the Patent Acknowledgements and Assignment of Rights signed by the breeders, and is attempting to obtain a copy.

Without more information on the pedigrees of the selections in the germplasm collection, it may be difficult to obtain patents for new varieties, and the lack of information may pose a problem for a new breeder trying to continue the breeding program. In her report, the consultant remarks that the lack of information on advanced selections is a serious limitation going forward and remedying it should be a top priority.

Recommendation

1. CA&ES and Campus Counsel should consider retrieval of more detailed information about the strawberry germplasm collection a top priority. The information should include pedigrees and performance data on the varieties.

Management Corrective Actions

a. This recommendation is addressed in the remediation plan from CA&ES management, Attachment VIII.

3. Practices to legally protect the strawberry germplasm collection could be enhanced.

I. The breeders tested new varieties for several years before making the decision to seek a patent. During the time before a patenting decision was made, the breeders participated in the standard Field Day presentations which highlighted promising new strawberry selections and international symposiums. While there is limited risk to the University unless an unauthorized individual has access to both information regarding a selection and the actual plant material, these types of events can provide access to both.

The University has several options to protect promising selections prior to the decision to commercialize a variety. A provisional patent can be filed on multiple selections, though this option can be cost prohibitive and impact the life of the regular patent, should one later be filed. A second option is to genotype promising selections. Genotyping will provide data on a selection's specific genetic make-up that can be used to help substantiate the University's claim to that selection, if necessary. In the past, genotyping was lengthy and expensive process, but it can now be done more simply and cost effectively.

After the start of the audit, UC Davis applied to patent all 169 advance selections in the germplasm collection. In preparation, UC Davis Foundation Plant Services genotyped all 169 advance selections. Therefore, decisions regarding the best methods to legally protect the strawberry germplasm will need to be applied to selections developed in the future.

Recommendation

1. Innovation*Access* should work with the new breeders to ensure they have an understanding of the relevant considerations for the protection of IP for the SBP.

2. Innovation*Access* and CA&ES should collaborate to identify the best method to protect the IP of the SBP prior to the actual patenting of varieties to be commercialized.

Management Corrective Actions

a. By August 15, 2015, Innovation*Access* will work with the new breeder to ensure that he understands relevant considerations in protection of IP rights.

b. By August 15, 2015, Innovation*Access* and CA&ES will collaborate and identify an earlier point in the plant breeding cycle when new varieties will be recognized as potentially valuable, and what method will be used to protect this IP before patenting.

II. Lassen Canyon Nursery (LCN) propagates the large number of plants used to test selections that are in the process of being commercialized (the "near-commercial" trials). LCN does not charge UC Davis for the propagation and historically, no agreement between UC Davis and LCN for this service has been issued. Although LCN provides the service for free, it should be governed by an agreement that includes specific language forbidding LCN from using any proprietary information or UC Davis germplasm as well as specifying UC Davis' ownership of the germplasm. These types of agreements at UC Davis are commonly called Breeder/Grower agreements.

LCN also propagates and distributes plants to the licensees for new releases. LCN grows the plants and notifies FPS of the number of plants available for distribution. FPS allocates the available plants among licensees that have placed orders, and tells LCN how to allot the plants among the licensees. LCN distributes the plants and then bills FPS for the service. FPS pays LCN and in turn bills each licensee for the plants they ordered. In order to be able to pay LCN, FPS creates a business contract after the fact. FPS writes this contract after LCN notifies them of the number of plants available so the contract can include specifics on how many plants were distributed. An agreement type that does not require this specificity would be more appropriate in the situation. A blanket purchase order does not require a total number of units, and could be used to set a firm per-plant price and specify UC Davis' ownership of the IP. University of California policy BFB BUS-43, *Material Management*, requires UC Davis to have an agreement in writing in advance of any work to protect the interests of the University. As with the propagation of near-commercial plants discussed above, this service should be governed by a contract or business agreement which is in place before LCN receives any germplasm.

Recommendation

1. Innovation*Access* and FPS should work together to ensure that no plants or other types of germplasm are turned over to outside parties, including LCN, before an agreement is in place that governs the relationship and protects UC Davis' IP rights.

Management Corrective Actions

a. By August 15, 2015, Innovation*Access* will work with the new breeder and with FPS and determine the appropriate form of written agreements and will ensure that future arrangements with LCN and other outside parties are covered by written agreements in advance of plant transfer.

4. Practices were not sufficient to protect the strawberry germplasm collection and pedigree database from theft or loss.

I. The pedigree database for the germplasm has safeguards against unauthorized access. However, there is an opportunity to increase the security of this valuable data to protect it against alteration, theft or loss.

Recommendation

1. CA&ES and greenhouse management should increase security over this important information. CA&ES should work with IT to ensure effective backup protocols, implement access and change management controls, and protect the data as required by BFB-IS-3, *Electronic Information Security*.

Management Corrective Actions

a. This recommendation is addressed in the remediation plan from CA&ES management, Attachment VIII.

II. At the time of the audit, entry and exit controls in the greenhouse where the plants are stored needed improvement. Since then, CA&ES has acted to increase the physical security at the greenhouse, adding electric locks, installing additional keypads, issuing programmable key fobs for access and upgrading the alarm system.

Recommendation

1. No recommendation is considered necessary, since CA&ES has improved the physical security at the greenhouse.

III. At the time of the audit, the plants in the collection were cataloged with the information included when the germplasm copy was transferred to UC Davis' control. With this data, it might be possible for someone to identify a particular seedling, risking the loss of important IP, and presenting a challenge for future breeding. According to the consultant, best practice would be to use a code to identify the plants.

Since the audit, greenhouse staff has taken steps to more securely identify the plants. Additional protections will be implemented once the new breeder has provided input.

Recommendation

1. CA&ES and greenhouse management should evaluate alternatives and implement a more secure system for identifying the plants in the germplasm collection.

Management Corrective Actions

a. This recommendation is addressed in the remediation plan from CA&ES management, Attachment VIII.

IV. At the time of the audit, the germplasm collection did not have sufficient copies of each variety. The germplasm collection had two plants of each variety. This is the same number of plants that were transferred to UC Davis in December 2013 and have since been maintained in a greenhouse. The Greenhouse Manager had to request replacements from the breeders for a few of the selections that died. To prevent loss of valuable IP, the collection should have more than two copies, especially of the more valuable advanced selections. Breeder A told Internal Audit he had a complete copy of the germplasm in cold storage. It was unclear what would happen to that germplasm at his retirement. UC Davis should create an additional copy of the germplasm and maintain it in cold storage. The consultant advised that any propagation of additional plants should begin with the most valuable, the advanced selections. Copies of the other selections could be grown as space allows.

Recommendation

1. CA&ES should verify that Breeder A returned all plants and other germplasm in his possession at the time of his retirement and develop a plan to increase the number of copies of each variety in existence. A duplicate copy of the collection should be kept apart from the main collection. An offsite duplicate copy will better safeguard the collection from the complete loss of a variety.

Management Corrective Actions

a. This recommendation is addressed in the remediation plan from CA&ES management, Attachment VIII. The germplasm and other information transferred to the custody of UC Davis may not contain all of the IP belonging to UC Davis.

5. Innovation*Access*' database for tracking shipments only covers international shipments and may not meet UC electronic security standards.

I. The database Innovation*Access* uses to track international shipments of strawberries was created in partnership with Eurosemillas, S.A. (ESA) to address business needs in Europe. As a result, the database does not include information on domestic shipments. A new database, specifically designed for the needs of the Strawberry Licensing Program, could contain information about shipments within California and the US as well as internationally. The database could also be designed to include information that could help Innovation*Access*, UCOP and FPS automate some of the manual checking they do to ensure only licensed nurseries receive plants, and the royalty payments from the licensees are accurate and complete.

The current database is web-based and most licensees, ESA, and UC Davis have access. It is unclear what security protocols are in effect over the data and whether the database complies with UC Davis policy on data protection. A database designed to meet the needs of Innovation*Access* could incorporate security to limit access, improve change management controls, and protection against the alteration, theft or loss of the information as required by BFB-IS-3, *Electronic Information Security*.

Recommendation

1. Innovation*Access* should evaluate the benefits and costs of developing its own database for tracking licensees and plant shipments. Any database developed by Innovation*Access* should comply with all security requirements in policy.

Management Corrective Actions

a. By February 15, 2016, Innovation*Access* will complete an evaluation of the benefits and costs of a database for tracking plant shipments solely controlled by UC and compliant with BFB-IS-3.

II. The territory for Master Licensee ESA has expanded over the years and now covers 19 countries throughout Europe, South America and the Middle East. There are currently four master licensees in addition to ESA, serving sub-licensees in New Zealand, South Africa and Australia. Only Australia has another master licensee with a significant territory. While UC Davis has been satisfied with their performance, such a large presence by ESA could act as a barrier to competitors. Given Breeder A's retirement and close relationship with ESA, it may be appropriate to evaluate UC Davis' relationship with ESA to ensure it continues to operate in UC Davis' best interests.

Recommendation

1. Innovation*Access* should continue to use performance metrics to monitor the performance of ESA and determine whether reassigning territories or seeking bids from additional companies would benefit the Strawberry Licensing Program and UC Davis.

Management Corrective Actions

a. In the event the licensing program enters into new territories by February 15, 2016 or thereafter, Innovation*Access* will seek bids from additional companies. Innovation*Access* will also continue to monitor the performance of Eurosemillas through February 15, 2016 and thereafter, to ensure the relationship continues to serve the best interest of the University.

D. PROGRAMMATIC REVIEW

As part of this project, UC Davis contracted with a faculty member from Cornell University, an expert in plant breeding, to review the programmatic operation of the SBP. Many of her conclusions support the observations of Internal Audit Services and have been mentioned earlier in this report.

The consultant's full report is attached as Attachment VII.

ATTACHMENT I: REVISED EXHIBIT A, ACCOUNTING AT UC OFFICE OF THE PRESIDENT

FY Revenue Earned (1)	Gross Strawberry Licensing Revenue	Net Patent Expenses	Non Patent related Expenses (2)	Inventor Share Payments (3)	Strawberry Portfolio Management Expenses (4)	Operating Charges (5)	Net to Davis
2004-05	$4,903,507	$201,440	$230,230	$1,842,363	$0	$222,578	$2,406,896
2005-06	$4,772,625	$148,043	$293,254	$1,880,967	$0	$189,216	$2,261,145
2006-07	$4,045,256	$65,175	$349,853	$1,734,329	$0	$178,268	$1,717,631
2007-08	$4,556,904	$221,438	$298,992	$1,591,251	$0	$69,252	$2,375,971
2008-09	$5,184,905	$434,176	$348,980	$1,700,824	$14,008	$95,020	$2,591,897
2009-10	$5,798,522	($332,408)	$329,851	$1,874,212	$150,936	$57,680	$3,718,251
2010-11	$6,985,224	$159,251	$386,598	$2,198,573	$293,710	$67,679	$3,879,413
2011-12	$6,995,706	$13,659	$352,736	$2,606,461	$188,848	$63,027	$3,770,975
2012-13	$7,581,120	($134,071)	$153,966	$2,649,626	$199,601	$62,213	$4,649,785

(1) There is a lag between the time revenues are earned and when campus receives the funds, and again when campus distributes the funds. This chart reflects allocations based on when the revenue was earned, not when distributions were made.

(2) Non-patent expenses include: (i) the licensing program field representative costs; (ii) the strawberry commercialization program costs (costs associated with bulk-up of plants at the time of new variety release); and (iii) UC Davis Foundation Plant Services strawberry program costs.

(3) The University Patent Policy grants inventors the right to receive a portion of net income accruing to individual inventions. Inventor shares are calculated based on revenues earned and certain expense activity.

(4) Strawberry portfolio management expense is deducted from the Strawberry Program royalties & fees directly in accordance with a 2007 agreement between UCD Innovation Access and UCOP.

(5) Operating charges are assessed by UCOP for services provided to UC Davis by its Innovation Alliance and Services unit. Starting in FY 2008-09, the UCOP operating charges were allocated based on what type of patent (utility patent or plant patent) was filed. UC Davis files plant patents for strawberries. Prior to FY 2008-2009, operating costs were calculated without allocation based on patent types; therefore, the operating charges for FY 2004-05 through 2007-08 are estimates, which were calculated on the basis of direct expenses incurred for plant patents.

ATTACHMENT II: REVISED EXHIBIT B, BUDGET & INSTITUTIONAL ANALYSIS AT UC DAVIS

Distribution of "Net to Davis" Amount					
Department of Plant Sciences		College of Agricultural & Environmental Sciences		Campuswide	**Total Distributed**
Strawberry Breeding Program	Research and Educational Activities (1)	Strawberry Research Fund	Research and Educational Activities (1)	Research and Educational Activities (1)	
$99,364	$99,364	$0	$0	$2,208,168	$2,406,896
$74,622	$74,622	$0	$0	$2,111,901	$2,261,145
$123,329	$123,329	$0	$0	$1,470,973	$1,717,631
$178,646	$178,646	$0	$0	$2,018,679	$2,375,971
$224,642	$224,642	$59,381	$0	$2,083,232	$2,591,897
$306,149	$306,149	$144,076	$262,410	$2,699,467	$3,718,251
$556,848	$556,848	$203,690	$477,299	$2,084,728	$3,879,413
$659,234	$659,234	$210,402	$565,058	$1,677,047	$3,770,975
Not yet determined (2)	Not yet determined (2)	$241,448	Not yet determined (2)	Not yet determined (2)	$4,649,785

(1) Revenue supports research and educational infrastructure and programs and non-billed services, in accordance with UCOP policy and is consistent

(2) Revenues earned in FY 2012-13 are not distributed until FY 2014-15 (with the exception of the distribution to the Strawberry Research Fund).

ATTACHMENT III: REVISED EXHIBIT C, STRAWBERRY BREEDING PROGRAM REVENUE & EXPENSES

	FY 2004 - 05	FY 2005-06	FY 2006 - 07	FY 2007 - 08	FY 2008 - 09	FY 2009 - 10	FY 2010 - 11	FY 2011 - 12	FY 2012 - 13	Total FY 05-13
REVENUES										
Strawberry Commission (1)	$ 350,000	$ 350,000	$ 350,000	$ 350,000	$ 350,000	$ 350,000	$ 350,000	$ 350,000	$ 350,000	$ 3,150,000
Non-CA Strawberry License Discount Fee Revenue (2)	$ 730,561	$ 696,866	$ 647,191	$ 769,163	$ 764,982	$ 636,538	$ 590,706	$ 594,971	$ 423,185	$ 5,854,163
Royalty (3)	$ -	$ 69,839	$ 99,364	$ 74,622	$ 123,329	$ 178,646	$ 224,642	$ 306,149	$ 556,848	$ 1,633,439
Plant Sciences (4)	$ 277,624	$ 7,094	$ 100,396	$ 193,719	$ 14,375	$ 148,479	$ 196,744	$ 156,679	$ 20,560	$ 1,115,670
UC Davis CA&ES (5)	$ 206,375	$ 214,535	$ 231,308	$ 248,229	$ 260,526	$ 263,712	$ 276,605	$ 290,948	$ 299,034	$ 2,291,272
Indirect Cost (6)	$ 318,394	$ 390,788	$ 378,743	$ 375,985	$ 400,922	$ 382,554	$ 330,773	$ 357,328	$ 366,753	$ 3,302,241
Total Revenues	**$1,882,954**	**$1,729,123**	**$1,807,002**	**$2,011,718**	**$1,914,134**	**$1,959,929**	**$1,969,470**	**$2,056,075**	**$2,016,380**	**$17,346,785**
EXPENSES										
Salary	$ 417,486	$ 601,134	$ 602,859	$ 607,589	$ 665,960	$ 672,628	$ 668,273	$ 623,883	$ 577,012	$ 5,436,824
Benefits	$ 143,065	$ 166,204	$ 217,550	$ 195,972	$ 237,523	$ 263,950	$ 279,502	$ 230,426	$ 240,115	$ 1,974,308
Supplies	$ 624,645	$ 665,676	$ 601,356	$ 608,080	$ 607,630	$ 501,682	$ 293,103	$ 492,331	$ 563,322	$ 4,957,826
Equipment	$ 4,383	$ 44,178	$ -	$ 6,471	$ -	$ -	$ 3,527	$ -	$ -	$ 58,559
Travel	$ 35,015	$ 25,841	$ 34,939	$ 27,985	$ 30,894	$ 33,102	$ 27,797	$ 27,696	$ 30,140	$ 273,410
Indirect Cost	$ 318,394	$ 390,788	$ 378,743	$ 375,985	$ 400,922	$ 382,554	$ 330,773	$ 357,328	$ 366,753	$ 3,302,241
Total Expenses	**$1,542,988**	**$1,893,820**	**$1,835,448**	**$1,822,082**	**$1,942,930**	**$1,853,916**	**$1,602,977**	**$1,731,664**	**$1,777,342**	**$16,003,167**
NET INCOME (LOSS)	**$ 339,967**	**$ (164,697)**	**$ (28,445)**	**$ 189,636**	**$ (28,797)**	**$ 106,013**	**$ 366,493**	**$ 324,410**	**$ 239,038**	**$ 1,343,618**

[1] Marketing board research contract from California Strawberry Commission

[2] Private contract funding from non-California discounted strawberry royalties

[3] Strawberry royalty funding allocated from the UC Davis Provost to Plant Sciences department

[4] Various sources of Plant Sciences department discretionary funding use to support the Strawberry Breeding Progam.

Sources include: annual "Commercialization Funding" to support bulk up of plant stock prior to release; various donor gifts; sale of fruit; University Extension; workshop & short course income; education & research funds.

[5] State general funds and indirect cost recovery funds

[6] Indirect costs were calculated at 26% of total expenditures

[7] Supplies include, but are not limited to: lease expense; utilities; maintenance & repairs; equipment rental; fleet services; contract farm labor; laboratory, field, & general supplies; environmental health & safety; telephone; mailing; business meeting & conference expenses

ATTACHMENT IV: UNIVERSITY OF CALIFORNIA TECHNOLOGY LICENSING PROGRAM

General background information

UC's technology transfer program operates under a model of distributed responsibilities and authorities that balances activities carried out by the central UC Office of the President (UCOP) with activities carried out by offices at the individual UC campuses. Under this distributed approach, the campuses develop and shape technology licensing programs to fit their unique needs as put forth in memoranda of understanding negotiated with UCOP.

UCOP is responsible for policy development and guidance, legal oversight, legislative analysis, information management and a variety of other services in support of the overall program.

Licensing and Related Activity

A license agreement grants a licensee access to a university invention in exchange for the licensee's commitment to further develop and commercialize the invention and to assist UC in gaining patent protection for the invention, often in multiple countries. The provisions of a license define the rights and responsibilities of the two parties. In managing these license agreements, UC collects monies when due and monitors progress to ensure that the licensees exercise due diligence in developing inventions toward commercial application.

Utility licenses generally cover useful processes, machines, manufactured items, or compositions of matter protected by utility patents, and are often exclusive licenses. In contrast, plant licenses cover sexually and asexually reproduced plant varieties, and most are non-exclusive licenses granted to multiple growers and distributors worldwide. UC works closely with some of its foreign plant licensees to explore opportunities for gaining IP protection and commercializing selected strawberry and other plant cultivars in countries where such IP rights had not been available previously.

Licensing Income

There are two components of licensing income. The royalty and fee income component includes agreement issue fees and maintenance fees. Generally, earned royalties account for the largest portion of royalty and fee income and are received once products and processes using UC inventions reach the marketplace. Reimbursements, the second component of total licensing income, represent the recovery of patent and legal expense.

Income Associated with Patent/Legal Expenses

Because inventions are highly technical, UC uses specialized outside attorneys to draft and secure patent protection both in the US and abroad. Costs to secure, maintain and protect patent rights associated with an invention are substantial. Obtaining a licensee's commitment to reimburse these costs is a high priority objective of license negotiations, and reimbursements, therefore, are considered part of total licensing income.

Legal and Other Direct Expenses

Most technology transfer legal expenses are associated with patent prosecution and maintenance, defined as payments to outside counsel for drafting patent applications as well as other costs for securing and maintaining patent protection for UC inventions. Other major categories of legal expenses include those for patent interference proceedings, enforcement of patent rights against infringement and defense against litigation in civil proceedings. The extent of reimbursement of legal and other direct expenses is a negotiated term of a license agreement.

Income Distributions
The income derived from royalties and fees, less the sum of payments to joint holders [such as other universities] and less net legal and other direct expenses, is distributed in various shares as required under UC and campus policies.

Inventor Shares
UC Patent Policy grants inventors the right to receive a portion of net income accruing to individual inventions. Under current UC policy, which applies to breeder B, inventors receive 35% of net invention royalties and fees, which are defined as: "gross royalties and fees, less the costs of patenting, protecting, and preserving patent and related property rights, maintaining patents, the licensing of patent and related property rights, and such other costs, taxes, or reimbursements as may be necessary or required by law." Under legacy UC policy, which applies to breeder A, inventors receive 50% of net royalties and fees, which are defined as: "gross royalties and fees, less 15% thereof for administrative costs, and less the costs of patenting, protecting, and preserving patent rights, maintaining patents, the licensing of patent and related property rights, and such other costs, taxes, or reimbursements as may be necessary or required by law." Inventor shares are calculated based on invention income and expense activity through the close of the prior fiscal year.

General Fund Share
The General Fund share is equal to 25 percent of the amount remaining after deducting payments to joint holders, net expenses and inventor share payments from royalty and fee income.

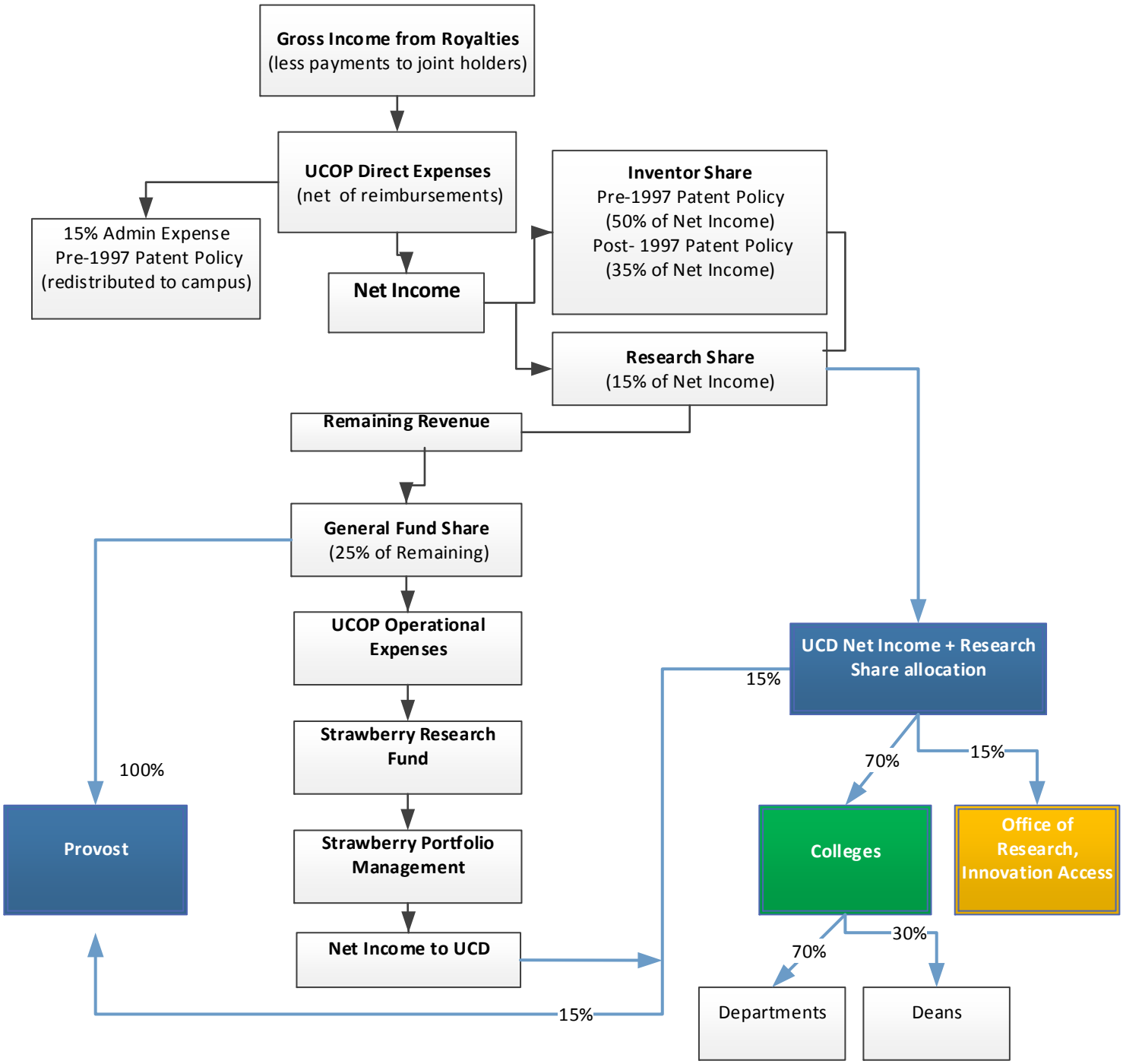
Research Allocation Share
The 1997 Patent Policy requires that for inventions disclosed on or after October 1, 1997 by inventors subject to this Policy, 15 percent of net royalty and fee income from each invention be designated for research-related purposes on the campus where the inventor worked at the time the invention was disclosed.

Income After Mandatory Distributions
All income derived from royalties and fees remaining after deductions for payments to joint holders, net legal and direct expenses, and other distributions, is available to the campuses subject to certain other campus-specific debits and credits for patent-related activities, e.g., the Strawberry Research Fund (described below).

Strawberry Research Fund
The provisions of the Strawberry Research Fund were established in a 2008 letter from Innovation*Access* to the CSC. The letter followed discussions between UC and the CSC and served to inform the CSC of Innovation*Access*' decision to increase royalty rates in California and establish the Strawberry Research Fund. Following are excerpts from the letter:

- The Strawberry Research Fund will be funded by contributions from 1/3 of the increase in the UC Davis share of strawberry royalty revenues resulting from the California royalty increase.
- The Strawberry Research Fund will be administered by the College of Agricultural and Environmental Sciences [the College] to support research including, but not limited to, plant sciences, horticulture, plant pathology and genetics that is directed at solving strawberry production issues in California.
- The College may choose to administer this fund as an endowment or to support current programs.
- The College will consult with strawberry industry representatives in the planning and implementation of the Strawberry Research Fund.

ATTACHMENT V: ROYALTY CALCULATIONS AND DISTRIBUTIONS



Legend: -> UCD Distributions
-> UCOP Distributions

ATTACHMENT VI: GLOSSARY

- **Advanced Selections** – Varieties that have performed well during testing and are put forward for further testing. Advanced selections are tested for four to six years before the breeders decide they should be patented.
- **Clean Stock –** Plants from Foundation Plant Services which are certified to be virus-free.
- **Clone –** A plant whose genetic information is identical to that of the plant from which it is created. Strawberries reproduce by creating runners. Nodes on the runners produce new plants (daughters) which are identical to the original (mother) plant.
- **Cross –** New strawberry genotype created by crossing two different varieties of strawberries.
- **Cultivar –** Strawberry variety which has a name. Also known as a "named variety".
- **Disclosure –** Release of information specific to a particular strawberry variety. Disclosures result from the filing of a variety release packet with Innovation*Access* or by giving out the information publicly, such as in a publication. Disclosure outside of UC Davis before a patent is sought can impact UC Davis' ability to patent the variety.
- **Elite Selections –** Another term for advanced selections.
- **Genotype –** The unique pattern of DNA specific to a particular strawberry. Also the name of the process to determine this pattern. (This process is also referred to as "DNA fingerprinting")
- **Germplasm –** Living tissue from which new plants can be grown.
- **Intellectual Property-** The strawberry germplasm and all information about the germplasm is Intellectual Property (IP). Depending on the context, IP may also include patent-related rights. This term can be used interchangeably with "strawberry germplasm" or "plants".
- **License –** Agreement between the UC Regents and a nursery that allows the nursery to grow and sell a particular patented UC Davis variety to fruit growers. A nursery needs a separate license for each patented variety, but multiple varieties may be covered in a single license agreement. Licensing activities are managed by the Strawberry Licensing Program, a unit of Innovation*Access* within the Office of Research.
- **Licensee –** Nursery within the U.S. or Canada that has obtained a license to grow and sell plants of UC Davis patented strawberry varieties
- **Master Licensee -** International company contracted by the Strawberry Licensing Program to oversee strawberry nurseries outside of the US and Canada (Sub licensees). Master Licensees grant licenses to, monitor, and collect royalties from, sub licensees. Master Licensees retain half of the collected royalties as payment**.**
- **Near-Commercial Tests**– Fruiting tests of advanced selections close to being patented. Done to familiarize growers and shippers with the performance of the new variety.
- **Patent Tracking System –** Web-based system used by the Innovation Alliances and Services unit at UCOP to record, monitor and report on all patent agreements and associated royalties.
- **Pathogen –** A virus, fungus or other organism which can damage or destroy strawberry plants.
- **Plant code names –** Designations used by the SPB to denote separate plant lines. Plant codes consist of the last two digits of the year of creation, plant family and seedling number, such as 11.195-3. The breeders also assign research code names (for example C229), which are sometimes used for the plant lines.

- **Plant Tracking System –** Web-based database created jointly with Master Licensee Eurosemillas, S.A. to monitor shipments of strawberry plants outside of the U.S. and Canada.
- **Record of Invention –** Document that notifies the UC Davis Innovation*Access* unit of the creation of a potentially patentable invention, in this case a new variety of strawberry.
- **Runner -** Long stems that grow sideways from the plants, with occasional nodes that each grow a daughter plant (clone).
- **Seedling –** Strawberry plant grown from seed.
- **Selection** – Any strawberry variety that performs well enough to be kept in the germplasm collection.
- **Strawberry Germplasm Collection –** The plants, runners or other plant parts of strawberry varieties created by the Strawberry Breeding Program (SBP) and determined by the breeders to be valuable enough to retain. Used to refer to the entire collection of UC Davis strawberry varieties.
- **Test Agreement –** Agreement between the Regents and a strawberry grower in which the grower agrees to use his land to grow varieties of strawberries so the breeders can evaluate the strawberries' performance. Agreement specifies the University's ownership of the strawberries and the rights and responsibilities of both parties.
- **Variety –** Plants resulting from breeding activities with a unique genotype.
- **Variety Release -** Process to commercialize a new strawberry variety by allowing its sale to licensees who then propagate the plants and sell them to fruit growers.
- **Variety Release Packet –** Information provided by the breeder to the Plant Variety Release Committee when the breeder recommends a patent be sought for a new strawberry variety.

ATTACHMENT VII: CONSULTANT REPORT

REVIEW AND ASSESSMENT OF THE UNIVERSITY OF CALIFORNIA DAVIS STRAWBERRY BREEDING PROGRAM

Susan K. Brown, PhD
Herman M. Cohn Professor of Agriculture and Life Sciences
Cornell University

June 22, 2014

TABLE OF CONTENTS

BACKGROUND

I was asked to perform this review and assessment of the Strawberry Breeding Program at University of California, Davis (UC Davis) to ascertain whether the UC Davis small fruit breeders were following best practices for plant breeding, including maintaining germplasm, organization, and completeness of breeding records. I was asked to contrast the UC small fruit breeding program with other fruit breeding programs nationally and internationally as to areas of research being examined and the thoroughness of the research approach. In this case thoroughness is defined as having the appropriate expertise, methodology and approach for sound science that culminates in peer-reviewed publication of the results and also extension deliverables (bulletins, webinars, and presentations). I reviewed the current status of the program and based on that review made recommendations on future changes that should be implemented. I also reviewed the program leaders for common expectations of University faculty for research, extension, mentoring of students and service.

WORK PERFORMED

To perform this review, I worked with UC Davis Internal Audit Services to gather and review information about the current condition of the strawberry germplasm, practices of the Strawberry Breeding Program, and UC Davis procedures. I also reviewed publications and the web site of the UC Davis breeding program, as well as those of comparable programs at other universities. I reviewed current literature in the field to determine current research topics and trends. Finally, I summarized topics by research areas and contrasted activities at UC Davis to those of other programs nationally and internationally. Under disease susceptibility, I highlighted research on specific diseases and summarized some of the susceptibilities of UC cultivars, as well as what research was being conducted at UC Davis.

I was not able to assess best practices in record keeping, nor thoroughness of information recorded because the breeding records were not available from the breeders. An inventory of plants being maintained was incomplete as to pedigree information. I expected more information to be available on the website or in progress reports and expected specific values for traits of interest rather than tables of plus/minus ratings of new selections in comparison to control cultivars (Shaw and Larson, 2014).

There were many opportunities highlighted for current and future research needs and each area was reviewed for current activities by other breeding programs and recommendations were made relative to the UC Davis program going forward.

Recommendations are summarized briefly below, with greater detail found within the report.

EXECUTIVE SUMMARY

Overall, I determined that the program has been successful at the release of new cultivars of commercial importance, but has overlooked important breeding targets, outreach approaches and opportunities for mentoring of undergraduate and graduate students. Given the scope of the program and the resources available, I would expect a web site with detailed information on each variety released, a link to the relevant patents and also to research reports on each cultivar. There are many exciting future opportunities/challenges in genetics, genomics and breeding. Fruit quality traits should be a focus, as should incorporating better resistance to common pathogens and complexes, especially in light of fumigation changes. Fruit nutritional components and flavor components (such as volatiles) would be promising areas of exploration. Greater collaboration would enhance pathology, plant physiology and postharvest attributes and are strongly recommended for expansion.

Specifically, in my review I noted:

- The pedigree information on the germplasm collection is incomplete and remedying this is a top priority.
- There is a lack of quantitative information available on the performance of UC Davis cultivars, specifically for color, firmness, Brix (sugar content), acid, volatiles (flavor components), and for disease susceptibility using replicated inoculations by plant pathologists.
- The program's breeders do not have same responsibilities for service, student training, extension quality (as defined by the amount and usefulness of information provided) and quantity, and publication of research results as researchers at other programs at UC Davis and at other programs nationwide.
- The program does not currently have any partnership with researchers from other disciplines such as plant pathology and soil sciences, though the expertise is available readily within the University.
- The breeders have a narrow focus and have not taken opportunities to study future threats and topics of interest in strawberry breeding, the most threatening being the loss of current fumigants. These fumigants control diseases to which many of the UC Davis cultivars are susceptible; the cultivars will perform poorly without fumigation.
- UC Davis is not participating in current research to advance strawberry genetics and genomics.

Based on my review of the program, I have the following recommendations for the program as it transitions to a new breeder:

- Disclosures or records of invention should be entered into the system at the first indication of potential for commercialization, not just before a patent is written.
- Pedigree information on the germplasm collection should include complete multigenerational pedigrees and test results for all advanced selections.
- The information available to growers and other researchers on new cultivars should be quantitative, with standardized scores for performance against all known pathogens and comparisons to all other cultivars in current commercial use.
- The breeder should take advantage of the scientific proficiency available at UC Davis to include expertise from other disciplines such as plant pathology in the program's research.
- The breeder and the program should be involved in activities to advance the field, including collaborating with researchers at other Universities, training graduate students and publishing research results.

OBSERVATIONS

Success in the release of varieties:
The UC Davis strawberry breeding has created cultivars that have been embraced by the industry in California and across strawberry production regions. They have added substantial value to the industry and to UC Davis. Commercialization of varieties is one metric where the program excels. The amount of funding and support that comes into this program is substantial and yet such support makes the lack of other metrics very surprising. One would expect a detailed website, active collaborations with the many excellent scientists at UC Davis, a cadre of students and visiting scientists that have been trained and a wealth of papers on all aspects of genetic improvement. The Principal Investigators (PIs) used to conduct research and publish their findings, but that has dropped off significantly since at least 2010.

Future challenges and the lack of collaborations:
With the future challenges, such as climate change, Spotted Wing *Drosophila*, loss of fumigants and new diseases associated with alternative methods, active partnerships across horticulture, plant pathology, entomology, soil science, postharvest physiology and food scientists (sensory and nutritional components) should already be in place to advance new materials to meet these challenges and to advance the science. Such partnerships are lacking, despite researchers available within the Plant Sciences department and across campus. These partnerships need to be fostered, using royalty funds to support collaborations as appropriate.

Contrast with other University small fruit breeders:
Drs. Shaw and Larson have bred strawberries, but have not met expectations of other University breeders, both within UC Davis and at other universities, as to service, student training, extension quality, (as defined by the extent and usefulness of information provided), and publication of results. Productivity, as defined by mentoring students, teaching, the number and quality of papers, presentations at conferences, and interdisciplinary collaborations with others, occurred relatively early in the program, yet the last 4 to 5 years appear to be spent primarily breeding. This contrasts with other programs such as Florida, where the breeding program has been releasing varieties and advancing scientific knowledge in many areas. Dr. Vance Whitaker has an active group studying many of these challenges and also looking at molecular markers, fruit quality and genetic parameters (http://gcrec.ifas.ufl.edu/faculty/whitaker.shtml). Publications from this group in 2014 detailed resistance to powdery mildew (Kennedy et al, 2014), candidate gene for flavor (Chambers et al., 2014), strawberry flavor and sensory perception (Schweiterman et al., 2014), trait prioritization in breeding (Yue et al., 2014) and gains in breeding for resistance to *Colletotrichum* (Osorio et al., 2014).

Narrow focus and failure to plan:
The UC Davis program has a reputation for focusing on yield and appearance, but not on quality. The cultivar release forms support that perception, with greatest focus on yield and size and appearance and little mention of non-subjective quality measures. Similarly, while disease resistance is mentioned, there is a consistent pattern of selective reporting on only some diseases and not others. Doug Shaw has been a vocal proponent of the power of methyl bromide, yet that emphasis has resulted in UC Davis varieties performing best on fumigated sites. Some of the varieties are very susceptible to diseases controlled by fumigation (Bolda et al., 2008, Shaw and Larson, 2014). This emphasis does not place the program or germplasm in a position to capitalize on new alternatives or offer growers more resistant varieties to aid in the transition away from this fumigant.

Research on nutritional components, quality attributes and genetic dissection of resistances are also lost opportunities, which other groups are pursuing. These studies will be detailed later, but in nutrition they are inclusive of research by Alvarez et al. (2014), Giampieri et al. (2014) and Diamanti et al. (2010, 2012, 2013).

Information shared about germplasm:
With Dr. Shaw's training in quantitative genetics, more quantitative metrics would be expected in patents and release notices to growers. The current bulletins only list qualitative assessments and that is not sufficient.

Recommendations for future release notices and performance evaluations:
Release notices should not be primarily qualitative in all ratings, as they currently are, rather they should contain values for cull rates, runner production in the nursery, mite tolerance, etc. The current system of using "+", "-" or "0" to indicate superior, inferior or similar to a named cultivar is not useful and is extremely subjective. Disease tolerance alone should not be a single category. The industry would find more comprehensive reports of greater use.

Where values of ratings based on inoculations are provided, the values should be provided for all the major pathogens of interest. In many release notices or presentations, only a few pathogens are discussed, leading one to guess as to the other susceptibilities.

The Plant Variety Release Committee needs to develop stricter protocols as to approval of variety releases. The breeder should not head the committee, regularly scheduled meetings should be held and minutes should be recorded. Approval of commercialization should state whether the vote was unanimous and if any concerns were expressed, what they were and how they will be handled.

Disclosures or records of invention should be entered into the system at the first indication of potential for commercialization, not just before a patent is written.

Disease Resistance Breeding:

There is no single paper or bulletin that summarized all the releases from the program for important pathogens. In addition, in surveying reports it becomes evident that yearly variation occurs across tests, suggesting that the methodology needs to be refined. With a program the size of this one, I would expect established protocols and agreements among breeders and pathologists. Some publications allude to a gain in resistance to pathogens such as *Verticillium*, yet many UC Davis varieties have a fatal flaw in susceptibility to one or more common pathogens. Attachment A on disease ratings shows how ratings change, and the table of varieties, Attachment B, shows that many are very susceptible to one or more pathogens. The information on these ratings was obtained from many different UC Davis reports or from the citations listed in the tables. Since susceptible plants have been used as parents, disease screenings of progeny are important to ensure that more susceptible offspring are not being commercialized. Attachment C, Disease Rating Scores, shows the three most recent releases 'Grenada', 'Fronteras' and 'Petaluma' all have susceptibility to *Colletotrichum* (1.9, 2.5 and 2.2 out of 5 rating, with 5 best), and 'Grenada' is extremely susceptible to *Fusarium* (1.2 rating). Attachment C was sourced from the UC Davis strawberry web site (Shaw and Larson, 2014).

This program has lacked sufficient emphasis on disease resistance breeding, and unfortunately it has failed to disclose the high susceptibility of some of its releases.
Field-testing in infested soil is probably not the best method for disease screening since there are problems with uniformity of pathogens. Long-term strategies should be implemented for loss of fumigants.

Recommendations for disease resistance breeding:

Collaborations with plant pathologists need to be resumed, with funds provided for this collaboration. Currently Drs. Shaw and Larson obtain inoculum from the pathologists for use in their trials. They do not pay for the inoculum and the pathologist is not part of their team. Perhaps this contributes to the variability on inoculation results. Breeders need to work in collaboration with pathologists to identify the proper isolates to use, determine whether the of host plant the isolate was collected from influences the results, and determine the effect of field assays as opposed to controlled inoculations. Pathologists should be involved in screening and inoculations. Further, diagnostics are needed to ensure that complexes such as "collapse" are understood.

Professional activities:

Drs. Shaw and Larson could arguably be considered as having one of the largest, well-funded plant breeding programs in the world, yet their national and international reputations are lacking because of their failure to collaborate with other breeders, attend scientific meetings, disclose research findings or train the next generation of breeders. They were not part of the large Specialty Crops Research Initiative (SCRI) project on marker-assisted breeding in the Rosaceae, yet their colleagues, including private breeders from Driscoll's, were involved (Mathey et al., 2013). The article by Yue et al. (2014) on producer priorities was also lacking participation by Shaw and Larson, despite the predominance of the CA industry.

They should be considered international experts, yet the Florida small fruit breeders wrote a recent chapter on "Strawberry" breeding in the text *Fruit Breeding* (Chandler et al., 2012), with no input from UC Davis breeders and a previous chapter on "Strawberries" in the text *Temperate Crop Breeding* also did not include Drs. Shaw or Larson as authors (Hancock et al., 2008). While Dr. Kirk Larson helped to organize a North American Strawberry symposium (Takeda, F., Handley, D. T., & Larson, K. D. (2013). Proceedings of the 2011 North American Strawberry Symposium. *International Journal of Fruit Science*, *13*(1-2), 1-2) it is noteworthy that Dr. Shaw did not present at this conference, with only a few conference presentations, one in Spain (Shaw, 2008) and one in China in 2012. Similarly, there has been little involvement in professional societies or genomics conferences (hosted in San Diego).

Collaborations/interactions with other programs:
Again, this is evident with other small fruit breeding programs outside of UC Davis. Researchers in small fruits in North Carolina and Florida have been collaborating and conducting studies across their different locations to examine genotype x environment interactions. The Florida strawberry industry has dedicated seven years of funding to advance marker-assisted breeding.

The UC Davis program does not seem to have used or investigated germplasm from the repository at Oregon**.**

Working with Extension:
Review of the literature and information on websites revealed the high quality outreach being done in California, despite a lack of engagement of the breeders with Extension. While Kirk Larson has contributed to the new disorders and diseases website (http://ucanr.edu/sites/sdim/), there are many more opportunities for effective partnering with extension personnel in addition to Kirk Larson.

Notably, Bolda's berry blog and the Dara blog (http://ucanr.edu/blogs/strawberries/) provide important information to the industry. In addition, Stephen Koike, UC Farm advisor, has conducted excellent studies and reviews of disease susceptibility of cultivars from the UC Davis program.

Listed below are extension personnel who work on strawberry and conduct research on UC Davis varieties but are not cooperators with the program:

- **Oleg Daugovish,** Strawberry and Vegetable Crop Advisor, UC Cooperative Extension-Ventura
- **Mark Bolda,** County Director, Santa Cruz County and Farm Advisor, Strawberries & Cranberries
- **Surendra Dara,** Strawberry and Vegetable Crops Advisor and Affiliated IPM Advisor
- **Steven Koike,** Plant Pathology Farm Advisor.

Recommendations for collaboration with Cooperative Extension:
This program has benefitted from the efforts of extension personnel in strawberries in addition to Kirk Larson, yet this relationship has been primarily one-sided. Efforts should be made to involve Cooperative Extension in aiding establishment of grower trials and monitoring plant performance as part of outreach activities in cooperation with the breeders. Funding should be sought for such collaborative projects.

GENERAL RECOMMENDATIONS

Program Disclosures and Testing

- The Test Agreements should not be signed by Dr. Shaw or Larson, but by Innovation Access for tracking. That ensures agreements are in place and that the University knows what is being tested and where it is being tested.
- Guidelines should be established as to the maximum number of plants of a selection that are allowed with a tester. Many universities specify an amount of plant material that should not be exceeded. The Test Agreements list number of plants, but the rationale as to the total number of plants allowed should be clearly articulated in writing. There should be discussion as to a maximum amount allowable.
- Test Agreements should be in place before any material is shipped. They should be in hand and the tester should provide a map of the planting.
- Expectations of tester reporting and data collection should be clear at the start of testing.
- Testers should understand that they should not share information on the test materials to media or on social network sites.
- Distinct codes should be used for material on test with growers. So for example materials sent in 2014 may be designated as 2014 a-z.

Breeding Program Web Site

The site should include the following information:

- A full list of strawberries patented, their pedigree and the US Plant patent number (Example attached- see Attachment B). This information will allow those who are interested to obtain additional information.
- A list of reported ratings for disease resistance susceptibility (Example attached- see Attachment C).

Future Steps and Supervising a New Breeder

- There should be a clear statement to all breeders to who "owns" germplasm developed.
- There should be discussion by the Regents as to whether the University of California Patent Policy clause allowing the assignment of patent rights to the inventor if the University elects not to file a patent should be maintained.
- There also should be a clear explanation of what claims Drs. Shaw and Larson have for both royalties and on commercialization decisions on future releases of materials developed under their tenure as scientists. Other Universities have dealt with such transitions. In many programs this has been based on trust. My recommendation is to establish a policy for this and any other programs. It is important that a specific university official has oversight and also has veto power over the previous breeders' input as to commercialization of materials derived from their materials. If Drs. Shaw and Larson argue against release of material an arbitrator should rule on this issue. If the arbitrator does not understand the breeding program and the materials they will not be effective.
- All scientists must meet standards for academic success and good University citizenship. These scientists should have been held accountable as are faculty at other Universities. There has been a "hands off" supervision style that contributed to the PIs feeling they are "untouchable". For a new scientist(s) there needs to be clear expectations as to accountability.
- Access to breeding records is usually not an issue raised, but given the removal of records by Drs. Shaw and Larson, in-house discussions are needed as to reasonable expectations for ensuring access to data. Every scientist has data that they may or may not share, so this is new ground.

Breeding, genetics and genomics

The new breeder and the geneticist being hired will face pressure from the industry to produce varieties, yet they will need to do all the professional activities that were not done by their predecessors. It is very rare to find someone in genomics that also shares a passion for development of new varieties. They exist, yet sometimes you hire one or the other. I would argue that both are very much needed and must be equal in position/title and in their respective roles. A geneticist/genomicist can address important issues for improvement, yet the breeding knowledge, the testing protocols, the ability to see subtle differences in phenotype and attribute the cause is also needed. A good team will move this program forward, but the lack of an integrated team or two independent programs would delay progress.

Intellectual Property (IP) oversight

The database for tracking materials in Europe and other territories should be a shared resource, not the sole purview of the master licensee.

Patenting of Advanced Selections

Discussions suggested that many advanced selections would be patented as a form of protection, yet this should be discussed further as too early a patent will reduce the patent life and the return of royalties to the program/UC Davis. Instead, a targeted list of high potential materials, such as newer selections that have been used frequently as parents would be the first group targeted for patenting.

Security of plant material

Since security of the strawberry collection is at issue in the lawsuit, I would recommend that a security camera be installed at the greenhouses and that the keys be changed. The cost of a card activated (scanned) lock should also be discussed, but as long as keys are inventoried this is not crucial. The plant identification should be changed to codes with only 1 or 2 individuals having access to codes.

In keeping inventory it is important that those entering the inventory use the full two or three code system with all leading zeros, otherwise the sorting does not work. In additional all plant materials that have alternative codes (C selection number) or names, should have those entered into the spreadsheet as well. There should be a complete master sheet that has all known pedigrees and their corresponding codes. Access to the master sheet should also be restricted to 1 or 2 people. Errors are evident in the inventory- as one variety is listed as Merced instead of Mojave. Such simple mistakes could have huge repercussions if stock plants are harvested from the wrong genotype.

OVERVIEW OF STRAWBERRY BREEDING RESEARCH

The following section summarizes recent issues in areas that this program should have been investigating more thoroughly.

Major pathogens to address
Anthracnose (*Colletotrichum acutatum*)
Angular leaf spot (*Xanthomonas Fragariae*)
Leaf blotch and stem end rot (*Gnomonia comari* -anamorph *Zythia Fragariae*)
Gray mold (*Botrytis cinerea*)
Powdery mildew (*Sphaerotheca macularis* f. sp. *Fragariae*)
Phytophthora crown rot, also known as red steele disease (*Phytophthora cactorum*) Verticillium wilt (*Verticillium dahliae*)

Anthracnose (Colletotrichum acutatum): Anthracnose of strawberry may be caused by any of three *Colletotrichum* species: *C. acutatum*, *C. gloeosporioides* or *C. fragariae*. These destructive pathogens infect fruit, leaves, petioles, crowns or roots and may cause plant death.

In a 2013 study, Miller-Butler et al. used traditional and molecular approaches to identify anthracnose resistant strawberry germplasm in a collection of 31cultivars and 46 selections. Following inoculation of whole plants with conidial suspensions of two *C. acutatum*, one *C. gloeosporioides*, and two *C. fragariae* isolates, 83% of the selections and 3% of the cultivars received a resistant score when averaged across the five isolates. The whole plant screening method was compared to a detached leaf assay in which leaves were removed from the 77 strawberry clones and inoculated in the laboratory with conidial suspensions of one *C. gloeosporioides* and two *C. fragariae* isolates, resulting in 78% of the selections and 3% of the cultivars rated resistant.

The 77 strawberry clones were screened for the presence/absence of two molecular markers reported to be linked to a *C. acutatum* resistant gene (*Rca2*) in strawberry germplasm. Among 39 clones rated resistant in the whole plant screen, 21 were positive for both and 14 were positive for one of the molecular markers. The authors suggested that correlation of the whole plant to the detached leaf assays and screening for the presence or absence of the *Rca2* gene could significantly reduce the time required to identify anthracnose-resistant genotypes (Miller-Butler et al., 2013).

Osorio et al. (2014) examined genetic variation and gains in resistance of strawberry to *Colletotrichum gloeosporioides*. This study used North Carolina and Florida field studies on the same material and calculated heritability at each sites. Garrido et al. (2009) suggested the use of real time PCR for detection and monitoring of this pathogen, but it is unclear if researchers adopted this approach.

Guidarelli et al. (2011) led efforts to understand why unripe fruit is resistant to anthracnose, yet ripe fruit are susceptible. The examined the interactions of *C. acutatum* with unripe and ripe strawberry fruits and investigated differential responses at histological and transcriptional levels. Later, this same group found that the mannose binding lectin gene *FaMBL1* is involved in the resistance of unripe strawberry fruits to *C. acutatum* (Guidarelli et al., 2014). Pardo et al (2012) examined the histopathology of resistance in wild materials and found an oxidative burst was associated with resistant versus susceptible materials related to resistance.

UC Davis cultivar susceptibilities:
'Camarosa' was very susceptible to anthracnose in Florida tests (Chandler et al., 2006). Fruit rot ratings in Florida listed 'Albion', 'Camarosa', 'Camino Real', 'Ventana' as susceptible/highly susceptible (Seijo et al., 2008). 'Grenada' and 'Merced' are also rated as susceptible (Shaw and Larson, 2014).

Angular leaf spot (*Xanthomonas Fragariae* anamorph *Zythia Fragariae*): Leaf spot has not been a focus of the UC Davis program, as it is rarely seen in California. However, other programs have placed emphasis on this pathogen. Jamieson et al. (2013) in Canada has focused on breeding strawberry plants resistant to angular leaf spot disease. The source of resistance is USDA germplasm from Beltsville that has introgressed resistance from *F. virginiana*. Challenges have included linkage drag with undesirable fruit traits and thus required repeated backcrossing and large populations. The percentage of resistant progeny increased from about 3% to 32% in recent crosses. Controlled inoculations are part of the protocol.

In another screening, only six genotypes of almost 200 accessions screened were classified as partly resistant, of which only two (US 4808 and US 4809) are octoploid. *F. vesca* , *F. alba*, *F. nilgerrensis* 'Yunnan', *F. vesca* 'Illa Martin', and *F. moschata* 'Bauwens' were classified as partially resistant, but they are only of limited use for breeding because of their deviating ploidy level (Bestfleisch et al., 2014).

Dried calyx disorder: Two UC Davis varieties, 'Camino Real' and 'Palomar' are known to have this physiological disorder (Whidden et al., 2008, Santos et al., 2009). Since these varieties have been used extensively as parents, their progenies should be examined to see how heritable this trait is and what percentage of offspring are affected.

> **Recommendation:**
> Given the frequent use of cultivars susceptible to dried calyx as parents in the breeding program, progeny should be studied as to the inheritance of this physiological disorder.

***Fusarium oxysporum* (*Fusarium oxysporum* f. sp. *fragariae*)**: *Fusarium* wilt of strawberry was discovered in California in 2008. Islas (2012) documented this pathogen in numerous fields in the largest strawberry growing districts in southern and northern California. Although pH of soil was implicated in the disease, there was no significant effect of pH, in the range of 5 to 8, on radial growth of the fungus in culture, and no consistent effect of pH on disease severity (Islas, 2012). Strawberry cultivars grown in California differ in susceptibility to *Fusarium* wilt.

Fang et al (2012) studied comparative root colonization of 'Camarosa' and 'Festival'. Later they conducted proteome analysis and revealed the importance of early activation of a defense response to resistance (Fang et al., 2013). Li et al. (2014) used qPCR to assess efficacy of fungicides and Paytner et al (2014) provided predictive breeding values based on his genetic studies.

> **UC Davis cultivar susceptibilities:**
> 'San Andreas' and 'Ventana' appear to have some tolerance to *Fusarium*, yet stress can impact this performance. 'Albion', 'Benicia' and 'Camarosa' scored poorly for this disease (Johnson, 2013). 'Camarosa' and 'Albion' are highly susceptible (Koike blog, 2014) 'Camarosa' was also found to be very susceptible in Australian studies (Fang et al., 2012).

Gray mold (*Botrytis cinerea*): Research in Florida found that assessment of cultivars for resistance to *Botrytis* fruit rot was more difficult due to low disease incidence. However, 'Camarosa', 'Florida Radiance', 'Florida Elyana', and advanced selections 99-117 and 99-164 showed good levels of resistance, whereas 'Camino Real', 'Ventana', 'Treasure', 'Candonga', 'Strawberry Festival', and 'Sweet Charlie' were more susceptible (Seijo et al., 2008). Wang et al. (2013) examined fruit differential protein patterns in strawberry cultivars susceptible or resistant to grey mold to gain insight as to mechanisms of resistance.

Leaf blotch and stem rot (*Gnomonia comari* –anamorph *Zythia Fragariae*): Moročko-Bičevska and Fatehi (2011) used a stain expressing green fluorescent protein to study infection and colonization of this pathogen.

Charcoal rot (*Macrophomina phaseolina*): First seen in California in 2008, and increasingly evident with the use of alternative fumigants. Infected plants develop a vascular dry rot in the crown that then causes plant collapse and death. Hutton et al. (2013) suggested that this pathogen would become increasingly problematic with the use of alternatives to fumigants.

UC Davis cultivar susceptibilities:
'San Andreas', 'Albion' and 'Portola' were reported to have susceptibility (Johnson, 2013). 'Camarosa' is most susceptible in Western Australia but 'Albion' is most resistant (Fang et al., 2012), perhaps attributed to differences in isolates. In Spain, inoculation resulted in 40% mortality in 'Camarosa' and 100% mortality with 'Ventana' (Avilés et al., 2009). Mertely et al. (2012) in an article on controlling charcoal rot suggested that 'Camarosa' had good resistance and 'Camino Real' was intermediate.

Strawberry Plant Collapse: Plant collapse appears to be attributed to a combination of *Fusarium* and *Macrophomina*, with susceptibility different than to single inoculation with one pathogen. 'Chandler' and 'Seascape' appear less prone to collapse (Koike et al., 2013). 'Ventana', 'Monterey' and 'Palomar' also had higher survival percentages against collapse (Koike et al., 2013).

***Phytophthora* crown rot, also known as red stele disease (*Phytophthora cactorum*):** A master's student in Oregon focused her thesis on phenotyping diverse strawberry germplasm for aid in marker-assisted breeding, and marker-trait association for red stele (*Phytophthora fragariae*) using resistance marker Rpf1 (Mathey, 2013). This is an example of the type of research projects feasible for students within the UC Davis program, for the betterment of the program and to train the next generation of researchers.

Schafleitner et al (2014) examined 107 genotypes and 37 selections and found that cold stored plants inoculated with *Phytophthora* were much better than plugs for assessing susceptibility and resistance and they allowed larger numbers of genotypes to be screened.

UC Davis cultivar susceptibilities:
'Diamonte', Gaviota, 'Parajo' and 'Ventana' are highly susceptible to *Phytophthora* crown rot (Browne et al., 2003).

Powdery mildew (*Sphaerotheca macularis* f. sp. *fragariae*): Nelson et al (1995) suggested that greenhouse tests might be useful in parental screening and early screening in the UC Davis strawberry breeding program. It is unclear if any screening is done for powdery mildew at UC Davis. In Florida, Kennedy et al. (2014) stated that additive genetic effects for resistance to foliar powdery mildew in strawberry were revealed through divergent selection.

UC Davis cultivar susceptibilities*:*
Not much information is available on line or in papers on this disease relative to UC Davis bred varieties. 'Ventana' fruits are known to be susceptible (Bolda et al., 2008).

Verticillium dahliae: Shaw et al. (2010) looked at the relationship between the extent of colonization by *Verticillium dahliae* and symptom expression and cautioned that distinguishing between tolerance and resistance required evaluations that supplemented visual assessment of resistance. Unpublished research by Shaw and Gordon suggested that frequency of colonization based on pathogen recovery from petioles provides this information, yet it is unclear if this methodology was pursued in breeding for resistance. These authors also suggested that quantitative PCR might be a more efficient method, yet again it is unclear if this line of research was pursued (Shaw et al., 2010).

In other research, Jęcz and Korbin (2010) reported that inoculation of micropropagated plants with wounded roots could be used as a tool to precisely distinguish strawberry genotypes tolerant and susceptible to *Verticillium* wilt disease. Diehl et al. (2013) examined field application of non-pathogenic *Verticillium dahliae* genotypes for regulation of wilt in strawberry plants.

Dressel et al. (2010) showed the importance of isolates tested in his controlled inoculation study in Germany and suggested a quantitative inheritance. Masny et al. (2014) conducted a combining ability analysis in 10 strawberry genotypes used in breeding cultivars for tolerance to *Verticillium* wilt and suggested parents which are likely to enhance resistance to *Verticillium*.

UC Davis cultivar susceptibilities:
'Camarosa' is susceptible to *Verticillium*. 'Benicia' also scores poorly on *Verticillium* and has season collapse issues attributed perhaps to a combination of *Fusarium* and *Macrophomina*. 'Mojave' strawberries are stated to be resistant to *Verticillium* wilt. 'Seascape' was rated susceptible in organic trials (Hoashi-Erhardt et al., 2013).

Virus: Martin and Tzanetakis (2013) reviewed high-risk strawberry viruses by region in the United States and Canada and discussed their effects on certification, nurseries, and fruit production.

UC Davis cultivar susceptibilities:
'San Andreas' is very susceptible to *Pallidosis* virus, with substantial economic losses reported in 2013 (Blake, 2013).

Arthropod pests: Collaboration with entomologists should be a priority in the future. Spotted Wing *Drosophila* (SWD) will be a future challenge, with genetic resistance unlikely, but harvest date a possible target for lessening infection. Spider mites have also been of interest. 'Benicia' has unusual coloration as a result of mite infestation. Bee pollination is another factor to consider for study. Klatt et al. (2014) found bee pollination increases crop quality, shelf life and commercial quality.

Recommendation:
Given the severity of what SWD means to the industry, an integrated approach to control options and study of new systems and their impact on cultivars should be undertaken. Potential areas of study include assessing whether the risk is increased by the use of high tunnels and/or soilless cultures, and whether all cultivars are uniformly susceptible or if the timing of harvest affects the severity of the damage. Entomologists should be an important member of a team investigating the genetic material, but also the material and the cultural conditions.

Color: The UC Davis program studied fruit color, yet their reports rely mostly on subjective evaluations, although their patents use colorimeter and other metrics. Sacks and Shaw (1993) examined color change in fresh strawberry fruit of seven genotypes stored at 0°C. Sacks and Shaw (1994) investigated optimum allocation of objective color measurements for evaluating fresh strawberries. However this research did not continue.

Research at Florida has estimated genetic parameters and gains for color traits of strawberry (Hasing et al., 2012). Transgenic studies revealed that there is premature and ectopic anthocyanin formation by silencing anthocyanidin reductase in strawberry (Fischer et al., 2014).

Recommendation:
External and internal color should be quantified in the UC Davis program, beyond what is done for plant patents. Internal color should be a trait evaluated.

Quality: There is a lack of quantitative ratings on plant and fruit attributes, despite Dr. Shaw's training as a quantitative geneticist. It is surprising that data presented to the industry frequently is not statistically analyzed, and little information is provided as to sample size used.

Brix and titratable acidity should be part of the metrics presented to the industry. While they are used in the patents, they often are not included in release notices or industry reports. Brix/acid measurements and their ratio are standard tests that every program uses, so their absence is surprising.

Further, there are great opportunities to examine consistency of fruit quality traits across sites, years and cultural conditions using these simple tests. For Brix, Hasing et al. (2013) showed within season stability for soluble solids content. A locus that affects acidity in strawberry, *TaV-M-2*, was identified by Zorrila- Fontanesi et al. (2011). Lerceteau-Köhler et al. (2012) conducted genetic dissection of fruit quality traits, while Liu et al. (2014) outlined the application of multispectral imaging to determine quality attributes and ripeness stage in strawberry fruit.

Recommendation:
Information to growers should include quality attributes such as Brix, titratable acidity and firmness values, rather than the qualitative assessments currently provided. Genetic dissection of specific sugars and acids important in UC Davis germplasm would help in selection of parents to transmit consistent high quality at different harvest seasons.

Sensory: It is unclear what facilities the UC Davis program has available for sensory testing of new materials. The Florida program has worked sensory assessment into its breeding program and assessment of potential releases. Other programs are also examining potential in this research area. Diamanti et al. (2014) examined the use of wild genotypes and found their use in breeding resulted in increases in strawberry fruit sensorial and nutritional quality. Vincent et al. (2014) found that instrumental measurements could not predict the sensory characteristics of strawberry clones, suggesting the need for sensory methodologies for the evaluation of new cultivars and selections. They suggested projective mapping as a quick alternative for evaluation of new cultivars relative to standard cultivars. This method allows a large number of cultivars to be screened without a lot of time or resources expended.

Recommendation:
Sensory testing of material likely to be commercialized should be conducted. This is important marker information, is useful to the industry and its addition will help to defuse criticism that quality has not been a breeding objective in the UC Davis strawberry breeding program.

Volatiles and Flavor: Volatiles have long been known to impact flavor, yet arguably one of the biggest breeding programs in the world has not examined this facet of fruit quality. Why hasn't there been research on volatile production and quality? The expertise exists at UC Davis for wine analyses, so application to strawberry is straightforward. Other groups are pursuing this area, as evidenced by just a few recent papers: Ulrich and Olbricht (2013) examined diversity of volatile patterns in sixteen *Fragaria vesca* L. (diploid) accessions in comparison to cultivars of *Fragaria× ananassa*. Josuttis et al. (2013) researched genetic and environmental effects on tannin composition in strawberry (*Fragaria× ananassa*) cultivars grown in different European locations. Additionally, Schwieterman et al. (2014) reviewed strawberry flavor in terms of its diverse chemical composition, seasonal influences, and effects on sensory perception. The UC Davis program is often criticized for emphasizing yield and appearance to the detriment of flavor, yet research on "flavor" is very much lacking. The Florida program is pursuing a candidate gene approach for strawberry flavor (Chambers et al., 2014). Researchers in Belgium are developing a high-throughput quality analysis platform to aid in discrimination and classification of cultivars and selections for quality (Vandendriessche et al., 2013). Their research has identified volatiles associated with immature fruits and ripe fruit.

Sanchez-Sevilla et al. (2014) studied gamma decalactone synthesis as one of the about 360 volatile organic compounds in strawberry that are characteristic of fruit aroma. Pan et al. (2014) took a unique twist on this and focused on the early detection and classification of pathogenic fungal disease in post-harvest strawberry fruit by using electronic nose and gas chromatography–mass spectrometry.

Recommendation:

UC Davis researchers possess the expertise and equipment to characterize existing materials and develop markers or metrics to enhance quality within the breeding program. Collaboration should be fostered.

Nutritional compounds in the fruit: Although the research area of nutritional compounds is incredibly complex and subject to large genotype x environment interactions, it is an important attribute for consumers and many studies are possible from a genetic perspective. Alvarez-Suarez et al. (2014) reviewed the importance of pre- and postharvest factors on strawberry nutritional content, while Giampieri et al. (2014) looked beyond antioxidants in terms of health benefits. Gündüz and Özdemir (2014) examined the role of genotype and growing conditions on phenolic content and individual acids and sugars.

Additional research includes that of Wang et al. (2014) on the distribution of phenolic components and their antioxidant capacity in strawberries. Medina-Puche et al. (2014) determined that MYB10 plays a major role in the regulation of flavonoid and phenylpropanoid metabolism during ripening of *Fragaria× ananassa* fruits. Jimenez-Garcia et al. (2013) reviewed functional properties and quality characteristics of bioactive compounds in berries, including biochemistry, biotechnology, and genomics.
Diamanti et al. (2010) suggested quality, nutritional quality and nutraceutical value as a new task for strawberry breeding. Later, funding was obtained to assess European small berries genetic resources. This project, "GENBERRY" is developing and testing protocols for detecting fruit nutritional quality in EU strawberry germplasm collections. (Diamanti et al., 2012). Subsequent research found that the use of wild genotypes in breeding program increases strawberry fruit sensorial and nutritional quality (Diamanti et al., 2013, 2014). Monfort (2014) summarized research on increasing strawberry nutritional quality using marker-assisted selection based on co-localization of mQTLs and e-QTLs linked to fruit polyphenol content.

Kårlund et al. (2014) looked at polyphenols in strawberry leaves induced by plant activators, while Currie et al. (2013) reviewed breeding for enhanced bioactives in berry fruit. Freeze-dried strawberries were found to lower serum cholesterol and lipid peroxidation in adults with abdominal adiposity and elevated serum lipids (Basu et al., 2014). Such results, on a limited number of varieties, show some of the potential of further explorations in this area.

Recommendations:

This is an exciting research area of interest to consumers and to the medical research community. At the very least there should be a survey of existing varieties and elites in the UC Davis program as to major antioxidant content, to help inform future breeding decisions. Focus should be on those antioxidants best known to be bioavailable and the best methods for their isolation should be researched.

Postharvest physiology and plant physiology: There are many world-class postharvest physiologists at UC Davis and elsewhere that would be eager to assist in this important aspect of strawberry quality. Kader (1991) and associates (Pelayo-Zaldívar et al., 2005, 2007) worked with the program in its early to middle years, yet subsequent efforts are lacking. Pelayo-Zaldívar et al. (2005) examined harvest date effects on flavor and other quality attributes of California strawberries, while Pelayo-Zaldívar et al. (2007) researched quality and chemical changes associated with flavor of 'Camarosa' strawberries in response to a CO_2-enriched atmosphere. Researchers in other regions are studying UC cultivars for postharvest attributes. The USDA program at Beltsville has developed protocols for assessing field rots and postharvest fruit decay (Lewers et al., 2012, 2013). Macnish et al (2012) examined covered pallet systems as a way to maintain fruit quality in transit. Many other studies are possible in the area of postharvest.

Recommendation:
The program should re-establish collaborations with postharvest physiologists at UC Davis.

Genomics, Genetics and Molecular Markers: While molecular marker research is difficult given the polyploidy of strawberry, I would have expected some activity in this area, and given the funding available, I would anticipate UC Davis leading the way in this research. Morales et al. (2011) assessed genetic similarity among strawberry cultivars using RAPD and ISSR markers. Zorrilla-Fontanesi et al. (2011) examined quantitative trait loci and underlying candidate genes controlling agronomical and fruit quality traits in octoploid strawberry (*Fragaria× ananassa*). Homeo QTLs and quality was a focus of Lerceteau-Köhler et al., 2012, while Chambers et al. (2013) used a genome-enabled, high-throughput, multiplexed fingerprinting platform and 16 high repeat SSRs to discriminate among over 200 varieties of strawberry.

The construction of an integrated high-density simple sequence repeat linkage map in cultivated strawberry (*Fragaria× ananassa*) will benefit breeding research (Isobe et al., 2013). Similarly, studies of comparative genomics of the Rosoideae will also be advantageous to future advances (Longhi et al., 2014).

Genetic studies include insights into the phylogeny, sex function and age of *Fragaria* based on whole chloroplast genome sequencing (Njuguna et al., 2013). In another study, ripening time and yield were studying using a diallel study by Bestfleisch et al. (2014a). Epigenetic control over several quantitative traits in diploid strawberry (*Fragaria vesca)* is being investigated by Xu (2014).

FUTURE ISSES TO BE INVESTIGATED

The following section summarizes recent issues in areas that this program should investigate in the future, preferably in collaboration with other scientists:

Loss of methyl bromide: Of all the areas looming on the horizon, the loss of soil fumigants has been foremost. There have been opportunities to lead in this area, coupling plant materials and new alternatives to fumigation, yet these opportunities were lost.

Browne (2013) reviewed the results of 7 years of research into alternatives to methyl bromide. Fennimore et al. (2013) detailed methods to facilitate the adoption of alternatives to methyl bromide soil fumigation by California strawberry growers. Soil biosolarization for sustainable strawberry production has been a focus of Domínguez et al. (2014). Gonzalez Fuentes (2014) examined plant and substrate based factors affecting design and management of in-field soilless strawberry production systems for his doctoral dissertation. There are opportunities to be at the forefront of this research, coupling plant and new productions systems.

Recommendation:
UC Davis varieties need to be screened as to their adaptation to soilless systems. Collaboration as to the best plant types to work in these systems is a necessary first step. Similar research was a focus of Hernanz et al. in 2007, when they assessed the differences in the phenolic composition of five strawberry cultivars grown in two different soilless systems. This research included UC Davis varieties.

Salinity: With the drought in California, salinity will continue to be an area needing research. Orsini et al. (2012) suggested that low stomatal density and reduced transpiration facilitate strawberry's adaptation to salinity. More research is needed in this area.

Robotic harvesting: Research on fruit detachment and classification methods for robotic harvesting of strawberry was already being examined six years ago (Feng et al., 2008). A 2013 grant of about 1.1 million dollars to UC Davis was to develop a small robotic aid to harvest strawberries (Martin, 2013), suggesting that there are future opportunities for this labor saving technology.

Recommendation:
Breeders need to partner with agricultural engineers and modelers to determine imaging software and metrics for fruit location and easy harvesting.

NEXT STEPS AND ESTABLISHING RESEARCH PRIORITIES

The University's lack of information on advanced selections is a serious limitation going forward. The inventory and pedigrees should be combined to develop pedigrees for as many parents as possible. The frequency of use as a parent should be summarized and recent selections that have already been used as a parent should be characterized further for patenting and breeding/genetic studies.

The review of recent literature shows how the UC Davis program is not leading in genetic studies of fruit quality, disease resistance or nutrition. Since there is so much ground to make up, a focus on quality and disease resistance is most appropriate in the short term, with the potential to add projects on other areas of research as the program is re-established.

REFERENCES CITED

Alvarez-Suarez, J. M., Mazzoni, L., Forbes-Hernandez, T. Y., Gasparrini, M., Sabbadini, S., and Giampieri, F. (2014). The effects of pre-harvest and post-harvest factors on the nutritional quality of strawberry fruits: A review. *J. Berry Research*, 4 (1), 1-10.

Amaya, I. (2014). Identification of the gene controlling g-decalactone content in strawberry fruit using two independent genetic and genomic approaches. In *Plant Animal Genome XXII Conference*.

Araus, J. L., Li, J., Parry, M. A. and Wang, J. (2014). Phenotyping and other breeding approaches for a New Green Revolution. *J. Integrative Plant Bio*.

Avilés, M., Castillo, S., Borrero, C., Castillo, M.L., Zea-Bonilla, T. and Pérez-Jiménez, R.M. (2009). Response of strawberry cultivars: 'Camarosa', 'Candonga' and 'Ventana' to inoculation with isolates of *Macrophomina phaseolina*. *Acta Hort.* 842, 291-294.

Basu A, Betts NM, Nguyen A, Newman ED, Fu D. and Lyons TJ. (2014) Freeze-dried strawberries lower serum cholesterol and lipid peroxidation in adults with abdominal adiposity and elevated serum lipids. J Nutr. Published ahead of print as doi:10.3945/jn.113.188169. http://www.strawberrynutritionnews.com/index.php/category/cardiovascular-health/#sthash.guZYPh4r.dpuf

Bestfleisch, M., Möhring, J., Hanke, M. V., Peil, A. and Flachowsky, H. (2014a). A diallel crossing approach aimed on selection for ripening time and yield in breeding of new strawberry (*Fragaria× ananassa* Duch.) cultivars. *Plant Breed.*, 133 (1), 115-120.

Bestfleisch, M., Richter, K., Wensing, A., Wünsche, J., Hanke, M. V., Höfer, M., Schulte, E. and Flachowsky, H. (2014b). Resistance and systemic dispersal of *Xanthomonas fragariae* in strawberry germplasm (*Fragaria* L.). *Plant Path.*

Blake, C. (2013) Strawberry growers face losses from pallidosis disease. Western Farm Press, August 5, 2013.

Bolda, M.P., Daugovish, O., Koike, S.T., Larson, K.D. and Phillips. P.A. (2008) Characteristics of strawberry cultivars commonly grown in California. UC IPM Pest Management Guidelines: Strawberry. UC ANR Publication 3468.

Browne, G. T. (2013). Outlook: Specialty crops and methyl bromide alternatives: Taking stock after 7 years. *California Agric.*, 67(3). Retrieved from: https://escholarship.org/uc/item/91r958rz

Browne, Greg, Harold Becherer, S. McLaughlin, S. Fennimore, J. Duniway, F. Martin, H. Ajwa, C. Winterbottom, and L. Guererro. (2003) Integrated management of *Phytophthora* on strawberry without methyl bromide." In *Proceedings Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions*, pp. 3-6.

Chambers, A., Carle, S., Njuguna, W., Chamala, S., Bassil, N., Whitaker, V. M., ...and Folta, K. M. (2013). A genome-enabled, high-throughput, and multiplexed fingerprinting platform for strawberry (*Fragaria* L.). *Mol. Breeding*, *31* (3), 615-629.

Chambers, A. H., Pillet, J., Plotto, A., Bai, J., Whitaker, V. M. and Folta, K. M. (2014). Identification of a strawberry flavor gene candidate using an integrated genetic-genomic-analytical chemistry approach. *BMC Genomics*, *15* (1), 217.

Chandler, C. K., Folta, K., Dale, A., Whitaker, V. M., & Herrington, M. (2012). Strawberry. In *Fruit Breeding* (pp. 305-325). Springer US.

Chandler, C.K., Metely, J.C., N. Peres. (2006) Resistance of selected strawberry cultivars to anthracnose fruit rot and botrytis rot. *Acta Hort*. 708, 123-126.

Currie, A., Scalzo, J., & Mezzetti, B. (2013). Breeding for Enhanced Bioactives in Berry Fruit. *Bioactives in Fruit: Health Benefits and Functional Foods*, 389-407.

Daugovish, O., Koike, S., Gordon, T., Ajwa, H., and Legard, D. (2011). Fumigant and strawberry variety evaluations in *Macrophimina phaseolina* and *Fusarium oxysporum* infested fields. *Int. Res. Conf. Methyl Bromide Alternatives and Emissions Reductions*

Diamanti, J., Capocasa, F., Battino, M. and Mezzetti, B. (2013). Inter-specific backcrosses and intra-specific crosses to generate strawberry genetic material with increased fruit sensory and nutritional quality. *Intl. J. Fruit Sci.*, *13* (1-2), 196-204.

Diamanti, J., Capocasa, F., Mezzetti, B., Battino, M., & Giampieri, F. (2010). Quality, nutritional quality and nutraceutical value as a new task for strawberry breeding. *Acta Hort. 926,*101-106.

Diamanti, J., Mazzoni, L., Balducci, F., Cappelletti, R., Capocasa, F., Battino, M., ... and Mezzetti, B. (2014). Use of wild genotypes in breeding program increases strawberry fruit sensorial and nutritional quality. *J. Agric. Food Chem*.

Diamanti, J., Sguigna, V., Mezzetti, B., Faedi, W., Maltoni, M. L., Denoyes, B., Chartier, P. and Petit, A. (2012). European small berries genetic resources, GENBERRY: testing a protocol for detecting fruit nutritional quality in EU strawberry germplasm collections. *Acta Hort.* 926, 33.

Diehl, K., Rebensburg, P. and Lentzsch, P. (2013). Field application of non-pathogenic *Verticillium dahliae* genotypes for regulation of wilt in strawberry pants. *Amer. J. Plant Sci.*, *4*, 24.

Domínguez, P., Miranda, L., Soria, C., de los Santos, B., Chamorro, M., Romero, F., ... and Medina, J. J. (2014). Soil biosolarization for sustainable strawberry production. *Agronomy Sustain. Dev.*, 1-9.

Dressler, A., Scheewe, P., Lentzsch, P. and Olbricht, K. (2010). Evaluation of strawberry cultivars for resistance to *Verticillium dahlia*e Kleb. *14th Ecofruit Intl.Conf. Organic Fruit Growing,* 350-352.

Fang, X., Jost, R., Finnegan, P. M., & Barbetti, M. J. (2013). Comparative proteome analysis of the strawberry-*Fusarium oxysporum* f. sp. f*ragariae* pathosystem reveals early activation of defense responses as a crucial determinant of host resistance. *J. Proteome Res.*, 12 (4), 1772-1788.

Fang, X., Kuo, J., You, M. P., Finnegan, P. M., and Barbetti, M. J. (2012). Comparative root colonization of strawberry cultivars Camarosa and Festival by *Fusarium oxysporum* f. sp. *fragariae*. *Plant and Soil*, 358 (1-2), 75-89.

Feng, G., Qixin, C. and Masateru, N. (2008). Fruit detachment and classification method for strawberry harvesting robot. *Intl. J. Adv. Robotic Systems*, *5* (1).

Fennimore, S. A., Serohijos, R., Samtani, J. B., Ajwa, H. A., Subbarao, K. V., Martin, F. N., Daugovich, O. and Klonsky, K. (2013). Methods to facilitate the adoption of alternatives to methyl bromide soil fumigation by California strawberry growers. *California Agric.*, 67, 139-146.

Fischer, T. C., Mirbeth, B., Rentsch, J., Sutter, C., Ring, L., Flachowsky, H., Habeggr, R., Hoffman, T., Hanke, M.V. and Schwab, W. (2014). Premature and ectopic anthocyanin formation by silencing of anthocyanidin reductase in strawberry (*Fragaria× ananassa*). *New Phytologist*, 201 (2), 440-451.

Folta, K. and Davis, F. (2006) Strawberry genes and genomics. *Critical Reviews Plant Sci*. 25, 399-415.

Garrido, C., Carbú, M., Fernández-Acero, F. J., Boonham, N., Colyer, A., Cantoral, J. M., and Budge, G. (2009). Development of protocols for detection of *Colletotrichum acutatum* and monitoring of strawberry anthracnose using real-time PCR. *Plant Path.*, *58* (1), 43-51.

Giampieri, F., Alvarez-Suarez, J. M. and Battino, M. (2014). Strawberry and human health: Effects beyond antioxidant activity. *J. Agric. Food Chem. (Advanced ahead of press)*

Gonzalez Fuentes, J. A. (2014). Plant and substrate based factors affecting design and management of in-field soilless strawberry production systems (Doctoral dissertation, Univ. California, Davis).

Goodhue, R. E., Bolda, M., Farnsworth, D., Williams, J. C., & Zalom, F. G. (2011). Spotted wing drosophila infestation of California strawberries and raspberries: economic analysis of potential revenue losses and control costs. *Pest Management Sci.*, 67 (11), 1396-1402.

Gordon, T. R., Kirkpatrick, S. C., Shaw, D. V. and Larson, K. D. (2002). Differential infection of mother and runner plant generations by *Verticillium dahliae* in a high elevation strawberry nursery. *HortScience*, 37 (6), 927-931.

Gordon, T. R., Kirkpatrick, S. C., Hansen, J. and Shaw, D. V. (2006). Response of strawberry genotypes to inoculation with isolates of *Verticillium dahliae* differing in host origin. *Plant Path.*, 55 (6), 766-769.

Gordon, T. R., Koike, S. T., Daugovish, O., Shaw, D. V. and Larson, K. D. A (2011) Comprehensive approach to management of wilt diseases caused by *Fusarium oxysporum* and *Verticillium dahliae*. AL *Production Research Report 2011.*

Gordon, T. R., Shaw, D. V., and Larson, K. D. (2009) *Verticillium* Wilt: Management through genetic resistance and suppression of inoculum in soil. AL *Production Research* 31.

Govindarajulu, R., Liston, A. and Ashman, T. L. (2013). Sex-determining chromosomes and sexual dimorphism: insights from genetic mapping of sex expression in a natural hybrid *Fragaria× ananassa* subsp. *cuneifolia*. *Heredity*, 110 (5), 430-438.

Gubler, W.D., Feliciano, A.J. and Su, H. Guide for identification of important diseases of strawberries in California.

Guidarelli, M., Carbone, F., Mourgues, F., Perrotta, G., Rosati, C., Bertolini, P. and Baraldi, E. (2011). *Colletotrichum acutatum* interactions with unripe and ripe strawberry fruits and differential responses at histological and transcriptional levels. *Plant Path.*, 60 (4), 685-697.

Guidarelli, M., Zoli, L., Orlandini, A., Bertolini, P. and Baraldi, E. (2014). The mannose binding lectin gene FaMBL1 is involved in the resistance of unripe strawberry fruits to *Colletotrichum acutatum*. *Mol. Plant Path*.

Gündüz, K and Özdemir, E. (2014). The effects of genotype and growing conditions on antioxidant capacity, phenolic compounds, organic acid and individual sugars of strawberry. *Food Chem.*155, 298-303.

Hancock, J. F., Sjulin, T. M. and Lobos, G. A. (2008). Strawberries. In *Temperate Fruit Crop Breeding* (pp. 393-437). Springer Netherlands.

Hasing, T., Osorio, L. F. and Whitaker, V. M. (2012). Estimation of genetic parameters and gains for color traits of strawberry. *Euphytica*, 186 (2), 303-311.

Hasing, T. N., Osorio, L. F. and Whitaker, V. M. (2013). Within-season stability of strawberry soluble solids content. *J. Amer. Soc. Hort. Sci.* 138 (3), 190-197.

Hernanz, D., Recamales, Á. F., Meléndez-Martínez, A. J., González-Miret, M. L., and Heredia, F. J. (2007). Assessment of the differences in the phenolic composition of five strawberry cultivars (*Fragaria× ananassa* Duch.) grown in two different soilless systems. *J. Agric. Food Chem.*, *55* (5), 1846-1852. Includes CA varieties

Hirakawa, H., Shirasawa, K., Kosugi, S., Tashiro, K., Nakayama, S., Yamada, M., ... and Isobe, S. N. (2013). Dissection of the octoploid strawberry genome by deep sequencing of the genomes of *Fragaria* species. *DNA Research*, dst049.

Hoashi-Erhardt, W., Moore, P., Collins, D., Bary, A. and Cogger, C. (2013). Evaluation of day-neutral cultivars for organic strawberry production in Washington. *Acta Hort.* 1001:167-174

Hummer, K. E., Bassil, N., and Njuguna, W. (2011). Fragaria. In *Wild Crop Relatives: Genomic and Breeding Resources* (pp. 17-44). Springer Berlin Heidelberg.

Hutton, D. G., Gomez, A. O., and Mattner, S. W. (2013). *Macrophomina phaseolina* and its association with strawberry crown rot in Australia. *Intl. J. Fruit Sci.*, *13* (1-2), 149-155.

Inderbitzin, P. and Subbarao, K. V. (2014). *Verticillium* systematics and evolution: how confusion impedes *Verticillium* wilt management and how to resolve it. *Phytopathology 104(6), 564-574.*

Islas, C. M. (2012) *Fusarium* Wilt caused by *Fusarium oxysporum* f. sp. *fragariae*: An emerging disease of strawberry in California. M.S. Thesis, Univ. California, Davis, 61 pages.

Isobe, S. N., Hirakawa, H., Sato, S., Maeda, F., Ishikawa, M., Mori, T., Yamamoto, Y., Shirasawa, K., Kimura, M., Fukami, M., Hashizume, F., Tsuji, T., Sasamoto, S., Kato, M., Nanri, K. Tsuruoka, H., Minami, C., Takahashi, C., Wada, T., Ono, A., Kawashima, K., Nakazaki, N., Kishida, Y., Kohara. M., Nakayama, S., Yamada, M., Fujishiro, T., Watanabe, A., and Tabata, S. (2013). Construction of an integrated high density simple sequence repeat linkage map in cultivated strawberry (*Fragaria× ananassa*) and its applicability. *DNA Research*, 20 (1), 79-92.

Jamieson, A. R., Hildebrand, P. D., and Renderos, W. E. (2013). Breeding strawberry plants resistant to angular leafspot disease. *Intl. J. Fruit Sci.*, 13 (1-2), 28-35.

Jęcz, T., and Korbin, M. (2010). Inoculation of micropropagated plants with wounded roots as a tool to precisely distinguish strawberry genotypes tolerant and susceptible to *Verticillim* wilt disease. *Phytopathologia* 58, 33-42.

Jimenez-Garcia, S. N., Guevara-Gonzalez, R. G., Miranda-Lopez, R., Feregrino-Perez, A. A., Torres-Pacheco, I., and Vazquez-Cruz, M. A. (2013). Functional properties and quality characteristics of bioactive compounds in berries: biochemistry, biotechnology, and genomics. *Food Research Intl.*, 54 (1), 1195-1207.

Johnson, B. (2013) UC Researchers develop strawberries with disease resistance. UC Davis Wordpress August 27, 2013.

Josuttis, M., Verrall, S., Stewart, D., Krüger, E., and McDougall, G. J. (2013). Genetic and environmental effects on tannin composition in strawberry (*Fragaria× ananassa*) cultivars grown in different European locations. *J. Agric. Food Chem.* 61 (4), 790-800.

Kader, A. A. (1991). Quality and its maintenance in relation to the postharvest physiology of strawberry. *The strawberry into the 21st century*. Timber Press, Portland, OR, 145-151.

Kårlund, A., Salminen, J. P., Koskinen, P., Ahern, J. R., Karonen, M., Tiilikkala, K., and Karjalainen, R. (2014). Polyphenols in strawberry (*Fragaria* x *ananassa*) leaves induced by plant activators. *J. Agric. Food Chem.*

Kennedy, C., Osorio, L. F., Peres, N. A., and Whitaker, V. M. (2014). Additive genetic effects for resistance to foliar powdery mildew in strawberry revealed through divergent selection. *J. Amer. Soc. Hort. Sci.*, 139(3), 310-316.

Klatt, B. K., Holzschuh, A., Westphal, C., Clough, Y., Smit, I., Pawelzik, E., and Tscharntke, T. (2014). Bee pollination improves crop quality, shelf life and commercial value. *Proc. Royal Soc. B: Biol. Sci.* 281 (1775), 2013-2440.

Koike, S. T. (2008). Crown rot of strawberry caused by *Macrophomina phaseolina* in California. *Plant Dis.*, 92 (8), 1253-1253.

Koike, S. T., Gordon, T. R., Daugovish, O., Ajwa, H., Bolda, M., and Subbarao, K. (2013). Recent developments on strawberry plant collapse problems in California caused by *Fusarium* and *Macrophomina*. *Intl. J. Fruit Sci.*, 13 (1-2), 76-83.

Landi, L., Feliziani, E., and Romanazzi, G. (2014). Expression of defense genes in strawberry fruit treated with different resistance inducers. *J. Agric. Food Chem.*

Lerceteau-Köhler, E., Moing, A., Guérin, G., Renaud, C., Petit, A., Rothan, C., and Denoyes, B. (2012). Genetic dissection of fruit quality traits in the octoploid cultivated strawberry highlights the role of homeo-QTL in their control. *Theor. Appl. Genetics*, 124 (6), 1059-1077.

Lewers, K. S., Luo, Y., and Vinyard, B. T. (2012). Evaluating strawberry breeding selections for postharvest fruit decay. *Euphytica*, 186 (2), 539-555.

Lewers, K. S., Luo, Y., and Vinyard, B. T. (2013). Evaluating strawberry breeding selections for field and postharvest fruit decay. *Intl. J. Fruit Sci.*, 13 (1-2), 126-138.

Li, Y., Mao, L., Yan, D., Ma, T., Shen, J., Guo, M., Wang, Q., Ouyang, C., and Cao, A. (2014). Quantification of *Fusarium oxysporum* in fumigated soils by a newly developed real‐time PCR assay to assess the efficacy of fumigants for *Fusarium* wilt disease in strawberry plants. *Pest Management Sci*. DOI: 10.1002/ps.3700.

Liu, C., Liu, W., Lu, X., Ma, F., Chen, W., Yang, J., and Zheng, L. (2014). Application of multispectral imaging to determine quality attributes and ripeness stage in strawberry fruit. *PloS one*, *9* (2), e87818.

Longhi, S., Giongo, L., Buti, M., Surbanovski, N., Viola, R., Velasco, R., Ward, J.A. and Sargent, D. J. (2014). Molecular genetics and genomics of the Rosoideae: state of the art and future perspectives. *Hort. Research*, doi:10.1038/hortres.2014.1.

Macnish, A. J., Padda, M.S. Pupin, F., Tsouvaltzis, P.I., Deltsidis, A.I., Sims, C.A. Brecht, J. K. and Mitcham, E.J. (2012). Comparison of pallet cover systems to maintain strawberry fruit quality during transport. *HortTechnology* 22, (4), 493-501.

Martin, J. (2013) USDA grants support federal partnership for robotics. USDA/NIFA Newsroom.

Martin, F. N. and Bull, C. T. (2002). Biological approaches for control of root pathogens of strawberry. *Phytopath.* 92 (12), 1356-1362.

Martin, F. (2013). Charcoal Rot of Strawberry.

Martin, R. R. and Tzanetakis, I. E. (2013). High risk strawberry viruses by region in the United States and Canada: Implications for certification, nurseries, and fruit production. *Plant Disease*, 97(10), 1358-1362.

Masny, A., Żurawicz, E., Pruski, K. and Mądry, W. (2014). Combining ability analysis in 10 strawberry genotypes used in breeding cultivars for tolerance to *Verticillium* Wilt. *J. Amer. Soc. Hort. Sci.*, *139*(3), 275-281.

Mathey, M. M. (2013). Phenotyping diverse strawberry (*Fragaria* spp.) germplasm for aid in marker-assisted breeding, and marker-trait association for red stele (*Phytophthora fragariae*) resistance marker Rpf1. Master's Thesis. Oregon State University.

Mathey, M.M. Finn, C.E. Mookerjee, S. Gündüz, K. Hancock, J.F., Iezzoni, A.F. Mahoney, L.L., Davis, T.M., Bassil, N.V., Hummer, K.E., Stewart, P.J., Whitaker, V.D., Sargent, J.D., Denoyes-Rothan,B., Amaya, I. and van de Weg, W.E. (2013) Large-Scale standardized phenotyping of strawberry in RosBREED. *J. Amer. Pomol. Soc*., 67(4) 205.

Medina-Puche, L., Cumplido-Laso, G., Amil-Ruiz, F., Hoffmann, T., Ring, L., Rodríguez-Franco, A., Caballero, J.L., Schwab, W., Munoz-Blanco, J. and Blanco-Portales, R. (2014). MYB10 plays a major role in the regulation of flavonoid/phenylpropanoid metabolism during ripening of *Fragaria× ananassa* fruits. *J. Exp. Botany*, 65 (2), 401-417.

Mertely, J. C., Seijo, T., and Peres, N. A. (2012). Controlling charcoal rot, an emerging disease of strawberry. *Phytopath.*, 102, (7) 80-80.

Mezzetti, B., W. Faedi, M. L. Maltoni, B. Denoyes, P. Chartier, A. Petit, J. Diamanti, and V. Sguigna. (2010). European small berries genetic resources, GENBERRY: Testing a protocol for detecting fruit nutritional quality in EU strawberry germplasm collections. *Acta Hort. 9*26, 33-37.

Miller-Butler, M. A., Curry, K. J., Kreiser, B. R., and Smith, B. J. (2013). Screening strawberry (*Fragaria* x *ananassa)* germplasm for anthracnose disease resistance using traditional techniques and molecular markers. *Phytopath.*103, (6), 97-97.

Monfort, A. (2014). Increasing strawberry nutritional quality: Marker assisted selection based on co-localization of mQTLs and e-QTLs linked to fruit polyphenol content. In *Plant and Animal Genome XXII Conference*.

Morales, R. G. F., Resende, J. T. V., Faria, M. V., Andrade, M. C., Resende, L. V., Delatorre, C. A., and Silva, P. R. D. (2011). Genetic similarity among strawberry cultivars assessed by RAPD and ISSR markers. *Sci. Agricola*, 68 (6), 665-670.

Moročko-Bičevska, I., and Fatehi, J. (2011). Infection and colonization of strawberry by *Gnomonia fragariae* strain expressing green fluorescent protein. *European J. Plant Pathology*, 129 (4), 567-577.

Nelson, M. D., Gubler, W. D., and Shaw, D. V. (1995). Inheritance of powdery mildew resistance in greenhouse-grown versus field-grown California strawberry progenies. *Phytopathology*, *85*(4), 421-424.

Nicolaï, B. N. T. V. B., Vandendriessche, T., Hertog, M., and Metabolomics, M. (2010). New developments in strawberry flavour research. *Status: published*.

Njuguna, W., Liston, A., Cronn, R., Ashman, T. L., and Bassil, N. (2013). Insights into phylogeny, sex function and age of *Fragaria* based on whole chloroplast genome sequencing. *Mol. Phylogenetics Evolution*, 66 (1), 17-29.

Orsini, F., Alnayef, M., Bona, S., Maggio, A., and Gianquinto, G. (2012) Low stomatal density and reduced transpiration facilitate strawberry adaptation to salinity. Environ. Exp. Botany, 81, 1-10

Osorio, L. F., Pattison, J. A., Peres, N. A., and Whitaker, V. M. (2014). Genetic variation and gains in resistance of strawberry to *Colletotrichum gloeosporioides*. *Phytopath.,* 104 (1), 67-74.

Pan, L., Zhang, W., Zhu, N., Mao, S., and Tu, K. (2014). Early detection and classification of pathogenic fungal disease in post-harvest strawberry fruit by electronic nose and gas chromatography–mass spectrometry. *Food Research International*, 62, 162-168.

Pardo, E. M., Grellet, C. F., Salazar, S. M., Castagnaro, A. P., Ricci, J. C., and Arias, M. E. (2012). Histopathology of the resistance to *Colletotrichum gloeosporioides* of wild strawberries and species related to commercial strawberry. *Australian J. Crop Sci.*, *6* (7).

Paynter, M. L., De Faveri, J., and Herrington, M. E. (2014). Resistance to *Fusarium oxysporum* f. sp. *fragariae* and predicted breeding values in strawberry. *J. Amer. Soc. Hort. Sci.*, *139* (2), 178-184.

Peeden, K. A. (2011). Effects of methyl bromide sterilization on the microbiota of two different strawberry systems.

Pelayo‐Zaldivar, C. L. A. R. A., Ebeler, S. E., and Kader, A. A. (2005). Cultivar and harvest date effects on flavor and other quality attributes of California strawberries. *J. Food Quality*, 28(1), 78-97.

Pelayo-Zaldívar, C., Abda, J. B., Ebeler, S. E., and Kader, A. A. (2007). Quality and chemical changes associated with flavor of 'Camarosa' strawberries in response to a CO_2-enriched atmosphere. *HortScience*, 42 (2), 299-303.

Pérez-Jiménez, R. M., De Cal, A., Melgarejo, P., Cubero, J., Soria, C., Zea-Bonilla, T., and Larena, I. (2012). Resistance of several strawberry cultivars against three different pathogens. *Spanish J. Agric. Res.*, 10 (2), 502-512.

Pillet, J. (2014). A systems biology approach to identifying genes associated with strawberry (*Fragaria x ananassa*) flavor and aroma. *Plant Animal Genome XXII Conference*.

Pincemail, J., Kevers, C., Tabart, J., Defraigne, J. O., and Dommes, J. (2012). Cultivars, culture conditions, and harvest time influence phenolic and ascorbic acid contents and antioxidant capacity of strawberry (*Fragaria* x *ananassa*). *J. Food Sci.* 77 (2), C205-C210.

Plotto, A., Baldwin, E., Bai, J., Narciso, J., Whitaker, V., and Chandler, C. (2014). Update on sensory evaluation of University of Florida strawberry selections. In *Proc. Florida State Hort. Soc.* 126, 247-250.

Porter, L. Trinder, D. Partington, J. Banks, S. Smith, M. Hannah and N. Karavarsamis (2006) Special Report: Validating the yield performance of alternatives to methyl bromide for preplant fumigation. *U.N. Environ. Programme Special Report Technology Economic Assessment Panel.*

Pritts, M. (2012). Managing farming systems, landscapes, pests and pathogens to improve consumer perception of berries. *J. Berry Research*, *2*(1), 1-6.

Rho, I. R., Woo, J. G., Jeong, H. J., Jeon, H. Y., and Lee, C. H. (2012). Characteristics of F_1 hybrids and inbred lines in octoploid strawberry (*Fragaria× ananassa* Duchesne). *Plant Breeding*, 131 (4), 550-554.

Sacks, E. J., and Shaw, D. V. (1993). Color change in fresh strawberry fruit of seven genotypes stored at 0C. *HortScience*, 28 (3), 209-210.

Sacks, E. J., and Shaw, D. V. (1994). Optimum allocation of objective color measurements for evaluating fresh strawberries. *J. Amer. Soc. Hort. Sci.*, 119 (2), 330-334.

Sánchez-Sevilla, J. F., Cruz-Rus, E., Valpuesta, V., Botella, M. A., and Amaya, I. (2014). Deciphering gamma-decalactone biosynthesis in strawberry fruit using a combination of genetic mapping, RNA-Seq and eQTL analyses. *BMC Genomics*, 15 (1), 218.

Santos, M.B., Chandler, C.K., Whidden, A.J. and Sánchez, M.C. 2009. Assessing the possible causes of the strawberry dried calyx disorder in Florida and Spain. *Acta Hort*. 842:829-832.

Schafleitner, S., Bonnet, A., Pedeprat, N., Rocca, D., Chartier, P., and Denoyes, B. (2013). Genetic variation of resistance of the cultivated strawberry to crown rot caused by *Phytophthora cactorum*. *J. Berry Research*, 3 (2), 79-91.

Schwieterman, M. L., Colquhoun, T. A., Jaworski, E. A., Bartoshuk, L. M., Gilbert, J. L., Tieman, D. M., Odabasi, A.Z., Moskowitz, H.R., Folta, K.M., Klee, H.J., Sims, C.A., Whitkar, V. A and Clark, D. G. (2014). Strawberry flavor: Diverse chemical compositions, a seasonal influence, and effects on sensory perception. *PloS one*, *9* (2), e88446.

Seijo, T. E., Chandler, C. K., Mertely, J. C., Moyer, C., and Peres, N. A. (2008). Resistance of strawberry cultivars and advanced selections to anthracnose and Botrytis fruit rots. *Proc. Fla. State Hort. Soc*., 121, 246-248.

Shaw, D. V., Gordon, T. R., Hansen, J., and Kirkpatrick, S. C. (2010). Relationship between the extent of colonization by *Verticillium dahliae* and symptom expression in strawberry (*Fragaria× ananassa*) genotypes resistant to *Verticillium* wilt. *Plant Path.* 59 (2), 376-381.

Shaw, D. V. and Larson, K.D. (2014) The UC Davis Strawberry Cultivar improvement Program announces the release of three short-day strawberry cultivars. UC Strawberry bulletin 2014-1. 7 pp.

Shaw, D.V. and Larson, K.D. (1999) A meta-analysis of strawberry yield response to preplant soil fumigation. *HortScience.* 34 (5), 839–845.

Shaw, D. V., Larson, K. D., and Gee, D. (2007). Performance of short-day cultivar Palomar at the South Coast REC, Santa Maria, and Watsonville Strawberry Research Facility in 2004-2006. California Strawberry Commission Strawberry Research Report, May 22, 2007.

Shaw, D. V., Gordon, T. R., Larson, K. D., Gubler, W. D., Hansen, J. and Kirkpatrick, S. C. (2010). Strawberry breeding improves genetic resistance to *Verticillium* wilt. *California Agric.* 64 (1).

Stegmeir, T.L, Finn, C.E., Warner, R. M. and Hancock, J.F. (2010) **Performance of an elite strawberry population derived from wild germplasm of *Fragaria chiloensis* and *F. virginiana*.** *HortScience*, 1140-1145

Tulipani, S. (2012). The nutritional quality of strawberries of different genotypes: preliminary studies on the impact of strawberry consumption on the antioxidant status of healthy subjects.

Ulrich, D., and Olbricht, K. (2013). Diversity of volatile patterns in sixteen *Fragaria vesca* L. accessions in comparison to cultivars of *Fragaria× ananassa*. *J. Applied Botany Food Quality*, *86* (1).

Ulrich, D. and Olbricht, K. (2014). Diversity of metabolite patterns and sensory characters in wild and cultivated strawberries. *J. Berry Research*, 4 (1), 11-17.

Vandendriessche, T., Geerts, P., Membrebe, B. N., Keulemans, J., NicolaÏ, B. M., and Hertog, M. L. (2013a). Journeys through aroma space: a novel approach towards the selection of aroma‐enriched strawberry cultivars in breeding programmes. *Plant Breeding*, *132* (2), 217-223.

Vandendriessche, T., Vermeir, S., Mayayo Martinez, C., Hendrickx, Y., Lammertyn, J., Nicolaï, B. M., and Hertog, M. L. A. T. M. (2013b). Effect of ripening and inter-cultivar differences on strawberry quality. *LWT-Food Science and Technology*, 52(2), 62-70.

Vandendriessche, T., Vermeir, S., Mayayo Martinez, C., Lammertyn, J., Nicolaï, B. M., Hertog, M. L. A. T. M., and Hendrickx, Y. (2011). High-throughput flavor evaluation of strawberry cultivars: focus on aroma development during ripening. *Acta Hort.* 945, 227-232.

van Dijk, T., Pagliarani, G., Pikunova, A., Noordijk, Y., Yilmaz-Temel, H., Meulenbroek, B., ... and van de Weg, E. (2014). Genomic rearrangements and signatures of breeding in the allo-octoploid strawberry as revealed through an allele dose based SSR linkage map. *BMC Plant Bio.*, *14*(1), 55.

Vicente, E., Varela, P., de Saldamando, L. and Ares, G. (2014). Evaluation of the sensory characteristics of strawberry cultivars throughout the harvest season using projective mapping. *J. Science Food Ag.*, 94(3), 591-599.

Wang, Y., Charles, M. T., Dong, W. X., Dubé, C. and Khanizadeh, S. (2014). Distribution of phenolic components and their antioxidant capacity in strawberries. *J. Food Research*, *3*(2).

Wang, Q., Dubé, C., Gagnon, C., Gleddie, S., Hao, Y. J., and Khanizadeh, S. (2013). Fruit differential protein patterns in strawberry cultivars susceptible or resistant to grey mold. *Archives Phytopath Plant Prot.*, *46*(7), 813-824.

Whidden, A. J., Sánchez, M. C., Santos, M. B., & Chandler, C. K. (2008). Assessing the possible causes for the" Strawberry Dried Calyx Disorder" in Florida and Spain. *Acta Hort. 842*, 829-832.

Whitaker, V. M. (2011). Applications of molecular markers in strawberry. *J. Berry Research*, 1 (3), 115-127.

Whitaker, V. M., Osorio, L. F., Hasing, T., and Gezan, S. (2012). Estimation of genetic parameters for 12 fruit and vegetative traits in the University of Florida strawberry breeding population. *J. Amer. Soc. Hort. Sci.*, *137* (5), 316-324.

Whitaker, V. M., Plotto, A., Hasing, T., Baldwin, E., & Chandler, C. K. (2013). Fruit quality measures from a historical trial of University of Florida strawberry cultivars. *Intl. J, Fruit Sci.*, 13 (1-2), 246-254.

Xu, J. (2014). Epigenetic control over several quantitative traits in strawberry (*Fragaria vesca). Plant and Animal Genome XXII Conference*.

Yue, C., Gallardo, R. K., Luby, J., Rihn, A., McFerson, J. R., McCracken, V., Whitkar, V., Finn, C., Hancock, J.,Weebadde, C., Seboldt, A., and Iezzoni, A. (2014). An evaluation of US strawberry producers' trait prioritization: Evidence from audience surveys. *HortScience*, 49 (2), 188-193.

Zorrilla-Fontanesi, Y., Cabeza, A., Domínguez, P., Medina, J. J., Valpuesta, V., Denoyes-Rothan, B., Sanchez-Sevilla, J.F. and Amaya, I. (2011). Quantitative trait loci and underlying candidate genes controlling agronomical and fruit quality traits in octoploid strawberry (*Fragaria× ananassa*). *Theor. Appl. Genetics*, *123* (5), 755-778.

****

ATTACHMENTS

UC Davis Strawberry Breeding Program Review and Assessment
Attachment A
Disease Rating Scores from some of the Release Notices

Below there are ratings made in different years (Table 1, years 2004 to 2006 for *Phytopthora)* and Table 2 scores from 2008 -2009, yet the absolute values are exactly the same. Given the variability admitted by the PIs- how are identical values possible?

In general, the 2014 scores indicate that new releases have serious susceptibility to major pathogens.

TABLE-1. Disease resistance scores for **`Mojave`** and three comparison cultivars. *Phytophthora* and *Verticillium* scores were obtained in evaluations conducted between 2004-2006; *Colletotrichum* was evaluated between 2005-2006.

	Phytophthora	*Verticillium*	*Colletotrichum*
	Resistance Score (5 = best)		
Genotype			
`Camarosa`	3.06	3.08	3.1
`Ventana`	2.06	2.89	2.7
`Palomar`	2.81	4.14	3.0
`Mojave`	2.31	3.75	2.7

TABLE- 2 Disease resistance scores for '**Benicia**' and three comparison cultivars.

	Phytophthora	*Verticillium*	*Colletotrichum*
	Resistance Score (5 = best)		
`Camarosa`	3.06	3.08	3.1
`Ventana`	2.06	2.89	2.7
`Palomar`	2.81	4.14	3.0
`Benicia`	3.50	2.08	2.6

Phytophthora and *Verticillium* scores were obtained in evaluations conducted between 2008-2009; *Colletotrichum* was evaluated in 2009.

TABLE-3 Disease resistance scores for **`Palomar`** and three comparison cultivars; *Phytophthora* and *Verticillium* scores were obtained in evaluations conducted in 2004-2006, *Colletotrichum* was evaluated in 2005-2006.

	Phytophthora	*Verticillium*	*Colletotrichum*
	Resistance Score (5 = best)		
`Camarosa`	3.6	2.5	2.6
`Camino Real	4.4	4.2	3.1
`Ventana`	2.5	3.0	3.0
`Palomar`	2.4	3.3	3.2

2014 report: Disease Resistance Scores: UC Cultivars & New Selections, 2011-13

Genotype	*Phytophthora*	*Verticillium*	*Colletotrichum*	*Fusarium*	*Macrophomina*
Camarosa	3.6	2.7	2.2	2.9	2.6
Ventana	2.1	2.9	3.0	4.2	4.3
Benicia	3.5	**1.6**	2.5	3.4	4.0
Merced	4.5	3.0	**1.8**	3.6	3.3
Petaluma	3.9	4.2	2.2	3.0	5.0
Grenada	3.9	3.3	**1.9**	**1.2**	4.7
Fronteras	4.1	3.7	2.5	4.9	5.0

References Cited:

Shaw, D. and Larson, K. (2014) The UC Davis Strawberry Cultivar improvement Program announces the release of three short-day strawberry cultivars. UC Strawberry bulletin 2014-1. 7 pp.

ATTACHMENT B

UC Davis Strawberry Table of Varieties

Cutivar	Code	Parentage	Inventor(s)	Date Rel.	Date patented	Code and Comments
Aromas	CN209	Cal **87.112-6** and Cal **88.270-1**	DV Shaw	1997	USPP 10,451	91.248.3
Diamante	CN210	Cal **87.112-6** and Cal **88.270-1**	DV Shaw	1997	USPP 10,435-1998	91.248.6
Gaviota	C205	Cal **87.112-6** and Cal **88.270-1**	DV Shaw	1997	USPP 10,461-1998	91.248.2
Pacific	CN211	Seascape x Cal **88.118-603**	DV Shaw	1997	USPP 10, 436-1998	91.324.1
Camino Real	C213	Cal **89.230-7** x Cal **90.253-3**	DV Shaw, KD Larson	2001	USPP13,079 2002.	94.3.11 strawberry dried calyx disorder
Ventana	C216	Cal **93.170-606** x Cal **92.35-601**	DV Shaw, KD Larson	2001	USPP13,469 - 2003.	96.42.601
Albion	CN 220	Diamonte x **Cal 94.16-1**	DV Shaw	2004	USPP 16,228-2006	97.117.3
Palomar	C221	Camino Real x Ventana (pooled of recipricol cross)	DV Shaw, KD Larson	2007	USPP 19472-2008	0.259.2 strawberry dried calyx disorder
Monterey	CN222	Albion x Cal **97.85-6**	DV Shaw, KD Larson	2008	USPP 19,767-2009	1-132-3
Portola	CN224	**Cal 97.93-7** and **Cal 97.209-1**	DV Shaw, KD Larson	2008	USPP 20,552 2009	1-206-5
San Andreas	CN223	Albion x **CA 97.86-1**	DV Shaw, KD Larson	2008	USP19,975 2009	1-39-2
Benicia	C225	Palomar x **Cal 0.18-601**	DV Shaw, KD Larson	2010	PPAP 2011	plant collapse issues Larson mites
Mojave	C227	Palomar x **Cal 1.57-601**	DV Shaw, KD Larson	2010	Patented in 2010/2011?	4-44-603
Petaluma	C231				Patented?	8-20-602
Grenada	C232				Patented?	8.55.2
Fronteras	C235				Patented?	8-132.608
Note:	**Cultivars in red are missing in germplasm**					

UC Davis Strawberry Cultivar Disease Ratings Scores

Cultivar	Anthr. *Colleto.*	leaf spot	charcoal rot *Marcophomina*	*Fusarium*	*Verticillium*	Collapse (F and M)	*Phytopthora*	Comments Source
Albion (220)	3.1		most res. **1.9**	**sus, 2.3.**	3.1, 3.4	poor (48.5% d), 4.0	4.4, 4.9-old data	Koike et al. 2013
Aromas (209)								V. sus. Rhizoctonia
Benica (225)	**2.5, 2.2**	**m. sus.**	4, 4.3, 4, 3.1	3.1, 3,4	**2.2, v. sus 1.6**		mod susp 3.5, 3.7	Patent
Camarosa (88.24.603)	**2.2, 2.8**		**2.6, 2.6,** 3.2	3.4, **2.9**	susc. **2.7**	22.4% dead 4.2	3.2, 3.6	Dressler, Chandler
Camino Real (213)		most res.	interm.	Resistant			Good resistance	
Chandler								
Diamonte (210)	2.6				**2.7**	4.9	**Highly sus.2.4**	
Fronteras (C235)	**2.5**		5	4.9	3.7		4.1	2014 bulletin
Gaviota (205)							**High sus.**	Browne
Grenada (C232)	**1.9**		4.7	**1.2**	3.3		3.9	Release notice
Merced (229)	**1.8**		3.3, 3.3	3.6	3		4.5	
Mohave (227)	2.7, 4.1		3.1	3.4	resistant 3.8		**2.3, 2.9**	
Monterey (222)	2.9		2.8	3.5	4.1, 4.2		3.9	
Pacific (CN211)								
Palomar (221)	3.9		3.2	3.4	3.1		3.3, **2.3**	Koike et al. 2013
Petaluma (C231)	**2.2**		5	3	4.2		3.9	
Portola (224)								
San Andreas (223)	2.8		**1.6**	5	4.1	30. 6% dead	4.1	Koike et al. 2013
Seascape (CN 49)								
Selva (CN 18)								
Ventana (216)	3, 2.7		**3.2,** 4.3	4.3. 4.2	**2.9**	tolerant, 3.9	**Sus. 2.1**	susp to P. Mildew
C230 8.17.5								
C231 8.20.602 = Petaluma								
C232 8.55.2 = Grenada								
C233 8.124.1								
C234 8.131.3								
C235 8.132.608= Fronteras								
C236 8.181.1								
Many different sources were used for this table, including release notices, and articles by Shaw, Larson, Browne and Koike.								

ATTACHMENT VIII: STRAWBERRY BREEDING PROGRAM REMEDIATION PLAN

Campus Strawberry Workgroup

The CA&ES Dean will form a UC Davis "Campus Strawberry Workgroup" (the Workgroup), a highest level internal working group dealing with policies and issues of non-academic, non-programmatic nature and comprised of representatives from the University organizations that play key roles in the Strawberry Breeding Program, including (but not limited to) Plant Sciences, the CA&ES Dean's Office, Innovation*Access*, Foundation Plant Services and UCOP Innovation Alliances and Services. Representatives from other campus business units such as the Office of Research, Campus Counsel, Budget and Institutional Analysis, and other offices as considered necessary will also be included on the Workgroup. The role of the Workgroup will be to ensure a coordinated and cohesive advisory approach to the overall management of the Strawberry Breeding Program while respecting academic freedom of the faculty member working on strawberry cultivar breeding research and educational activities.

The CA&ES Dean will keep the Chancellor informed on a regular basis as to the Workgroup's activities.

The Workgroup will also be charged with developing a short and long term strategic plan for the Strawberry Breeding Program. While developing the strategic plan, the Workgroup will meet on an as needed basis. When the plan is complete, the Workgroup will meet not less than semi-annually.

The Workgroup will be formed and formally charged by August 15, 2015.

Chair of Campus Strawberry Workgroup

A Chair of the Campus Strawberry Workgroup will be appointed by the CA&ES Dean. The specific roles and responsibilities of the Chair will be determined by the Dean in consultation with campus leadership and the Plant Sciences department and new breeder.

The Chair will be appointed and provided with a description of his/her roles and responsibilities by August 15, 2015.

Strawberry Breeding Program Strategic Plan

The Campus Strawberry Workgroup will develop a strategic plan for the Strawberry Breeding Program. The strategic plan will include a mission, vision and goals for the Strawberry Breeding Program that are in alignment with the Campus long-range goals to: 1) Advance excellence in teaching, research and service by actively promoting and nurturing interdisciplinary and collaborative programs that place student success at the core of everything we do; 2) Continue to streamline administrative operations by applying new and creative business practices; and, 3) Continue to diversify our revenue sources.

The strategic plan will also include action items to address the issues raised by the internal audit report. These issues include:

A) Financial Management and Reporting -
   1) Consider establishing a distinct financial organization for the Strawberry Breeding Program in the general ledger;
   2) Preparing annual financial reports for the Strawberry Breeding Program;
   3) Allocating of current and future Campus royalty revenues to breeders; and,
   4) Considering potential impact of Breeder A's company on future strawberry royalty revenues.

B) Licensing Fees and Royalty Revenues –
   1) Assessing the cost versus benefit of implementing a licensee auditing program.

C) Protection of Intellectual Property –
   1) Establishing clear definitions of authority and responsibility for positions with key roles in Strawberry Breeding Program, and organization structure that facilitates ability to effectively execute responsibilities;
   2) Working with the Plant Variety Release Committee to establish a shorter timeframe for filing of ROI disclosures to fully protect University interest in advance selections;
   3) Improving documentation of pedigree and performance information for germplasm collection;
   4) Genotyping of advance selections, and hiring a forensic geneticist to identify and pursue patent violations;
   5) Formalizing agreements with nurseries and growers receiving germplasm ahead of receiving services;
   6) Improving physical security of greenhouse plants;
   7) Increasing number of plants and/or amount of seeds needed in the UCD collection;
   8) Increasing security of data related to Strawberry Breeding Program; and,
   9) Assessing need for database to track licensees and plant shipments.

D) Enhancing Program Visibility -
   1) Improving information available to growers and other researchers on new varieties.

E) Other -
   1) Evaluating territory allocated to master licensees.
   2) Assessing potential conflict of interest of the retired breeders.

The strategic plan document will be completed by February 15, 2016.