Taking on the directorship of the SBC means that I have big shoes to fill. Kent Bradford always makes it look easy. In writing my opening essay as director, it is hard not to echo what Kent wrote in 2018 about our team. The statement “if you love what you do, you never work a day in your life” comes to mind. This is all about the people you work with, beginning with a great staff and colleagues who get it done, know when to be serious, and when to have fun. This is who the SBC is. I recently mentioned this to a long-time supporter of the SBC, Kelly Keithly, who quickly pointed out that this is the seed industry. Indeed this is true. What other industry uniquely has the common goal and drive to feed the world?

Kent is a quintessential academic but uniquely understands that sound science, translation and application of research are critical to success, defining the three pillars of the mission of the SBC: research, education and outreach. His drive is contagious and it is not a coincidence that Francois Korn and he built on the concept to create Seed Central. Similarly, Sue DiTomaso has been the glue that kept the SBC on track. As Associate Director, she has a unique personality and ability to bring people together and somehow get what seems like impossible tasks within the University system to happen. We will miss both Kent and Sue at the SBC, but they certainly have left a solid foundation to build on.

Likewise, Rale Gjuric brings critical experience in plant breeding and business, leading us to build an international Plant Breeding AcademySM and professional classes in seed production and seed business, now on four continents. As director of the SBC’s educational programs that have now trained 360 plant breeders in 68 countries and over 6000 people in the international seed industry, he has been named one of the most influential people in the industry. His way of simplifying even the most complex quantitative genetics concepts and explaining how they are applied in breeding programs ensures that class participants immediately leverage their new knowledge into their programs. In this transition year, I want to thank Rale for his leadership.

We have four positions to fill including a new faculty member focusing on seed biology. The first position filled is with Kelsey Maher, who has proficiently taken on some of Sue’s tasks and is supporting classes and Seed Central. I am happy to say we have excellent candidates for all positions.

The agricultural industry has been deemed essential under Covid-19 restrictions, re-emphasizing how important our work is. As part of a top University in the world in agriculture, I am proud to report that our Department of Plant Sciences is committed to maintaining our excellence with seven recent new faculty hires focusing on breeding for nutrition, high-throughput phenotyping, remote sensing, crop physiology, and plant reproductive biology, several co-located with the SBC. As a plant breeder, I was trained to think of systems approaches to achieve product goals for a certain target environment, to act locally and have global impact. This is the foundation and vision for the SBC, to ensure that the seed industry not only has access to the latest technologies, but to also have a workforce trained in how best to integrate those technologies into agriculture and to have the policies in place to deploy them sensibly. Nowhere and no time has this philosophy been more important with challenges in achieving food and nutritional security for the world.

Looking Forward

Allen Van Deynze
SBC Director

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California is perhaps the most productive and certainly a critical location for seed and crop production, due to its unique array of desirable environments and diversity of crops.

Francois Korn recognized this early on and aimed to make Seed Central the Silicon Valley of Seed centered on UC Davis. That was 10 years ago when Seed Central was born, highlighting Simon Chan’s revolutionary work at UC Davis on engineering haploids in crops. Its subsequent success is due to the presence of a diverse workforce critical to the seed industry, from agronomists, pathologists, nutritionists, healthcare professionals, lobbyists and the technologies that originated in the Silicon Valley, including computer and engineering technologies, genomics and remote sensing. The CRISPR/CAS9 gene editing technology from Jennifer Doudna’s group at UC Berkeley, long-read sequencing technology from Pacific Biosciences, 10x Genomics, Climate Corps, autonomous vehicles, and Google are all engaged with the agricultural and seed industries. The SBC and UC Davis colleagues work directly with these companies in research and connect them to you through Seed Central’s Innovators Showcase in January and in close coordination with the California Seed Association and the American Seed Trade Association.

Finally, I have been fortunate to work with another visionary person, Howard-Yana Shapiro (former Chief Agricultural Officer for Mars, Incorporated and Fellow at UC Davis), who understands the importance to “pay it forward” when it comes to our knowledge and expertise to achieve nutritional security for developing countries. The founding of the African Orphan Crops Consortium and establishing the African Plant Breeding Academy in 2013 has truly been a humbling experience, putting in perspective why we do what we do. It is consistent with SBC’s vision of working locally to have global impact.

In this 20th anniversary report, you will find a timeline with significant achievements by the SBC over the years in research, education and outreach that lay the foundation to meet the challenges of the future. I hope you enjoy reading our report.
The University of California, Davis (UC Davis) Plant Breeding AcademySM (PBA) has been offered since 2006 with classes in the USA, Europe, Africa and Asia. To date, the program has trained more than 360 breeders. The PBA is a postgraduate program that teaches the fundamentals of plant breeding, genetics and statistics through lectures, discussion, and field trips to public and private breeding programs. The program maintains its core curriculum in addition to upgrades that address the most recent developments in plant breeding theory and practice. The core instructors include internationally recognized experts in plant breeding and seed technology: Kent Bradford, Allen Van Deynze, Rale Gjuric (all UC Davis), Rita Mumm (University of Illinois), Todd Wehner (North Carolina State University), Iago Hale (University of New Hampshire and UC Davis graduate), Bruce Walsh (University of Arizona and UC Davis graduate) and Alexandra Tomerius (AIB). They are supported by a number of guest lecturers from the private industry and academia.

PBA Highlights in 2019

UC Davis European PBA Class V graduated

The UC Davis European Plant Breeding Academy (PBA) Class V held its fifth session in February in Almeria, Spain and its final session (and graduation) in June in Davis, California. During the six sessions over the last two years, 20 participants in this class spent more than 300 hours in classes, workshops and the field.

European PBA Class V course participants:

- Rami Abu Mousa, Oula for Seeds Production, Jordan
- Maria Berenguer Rivero, Semillas Fito, Spain
- Alexandra Bothe, Norddeutsche Pflanzenzucht Hans-Georg Lembke KG, Germany
- Richard Fages, HM.Clause, France
- Pablo Fernandez, Syngenta, Spain
- Benoît Foucault, KWS, France
- Darryn Gibson, Progeny, USA
- Rotem Hasson, BASF, Israel
- Juan Manuel Herrera, Agroscope, Switzerland
- Kadir Kaman, Syngenta, Turkey
- Edina Eva Kare, LS Plant Breeding, United Kingdom
- Cédric Lefaix, HM.Clause, Iberica SA, Spain
- Sina Möller, Deutsche Saatveredelung AG, Germany
- Stephanie Mueller, KWS, Germany
- Mihaela Patrascou, Maisadour Semences, Romania
- Edouard Penez, Saaten-Union Recherche, France
- Enrique Ramos, Syngenta, Spain
- Philipp Schulze, Royal Berries, Spain
- Ahmet Sirri Sensoy, Semillas Fito, Turkey
- Gregor Welna, Norddeutsche Pflanzenzucht Hans-Georg Lembke KG, Germany
UC Davis PBA Class VII continues

PBA class VII completed 4 out of 6 sessions and is set to graduate in June 2020.

UC Davis European PBA Class VI begins

Contributing to fill a critical need for trained plant breeders, the University of California, Davis European Plant Breeding Academy (EPBA) started its sixth class of students in October with a session in Gent, Belgium. The session was organized with the generous support of the local industry and the University of Gent and included visits to BASF/Crop Design and Flanders Research Institute for Agriculture, Fisheries and Food (ILVO).

Over the next two years, during the six sessions held in Gent, Belgium; Angers, France; Gatersleben, Germany; Enkhuizen, The Netherlands; Almeria, Spain; and UC Davis, this class will spend more than 300 hours in classes, workshops and the field, training to complete this premium professional program.
Africa Plant Breeding Academy Class IV graduates

In December, the PBA in Africa (AfPBA) graduated its 4th class at World Agroforestry (ICRAF) in Nairobi, Kenya, where all sessions are held. This brings the total graduates to 112, 87% PhD and 38% women from 27 countries. Over 13 months, 32 participants from 21 countries and 31 institutions throughout Africa spent more than 300 hours in the six-week program in classes, workshops and the field, training in the UC Davis Plant Breeding Academy. Instructors included experts from academia and industry professionals, including Rita Mumm (Director of AfPBA, University of Illinois), Allen Van Deynze, Kent Bradford, Rale Gjuric (all UC Davis), Iago Hale (University of New Hampshire), Bruce Walsh (University of Arizona), Todd Wehner (North Carolina State University). Special topics were covered by Darshna Vyas (LGC), Ronald Dorcinvil (Corteva, Inc.), Kendra Meade and Mike Thompson (Benson Hill), Alex Lipka (University of Illinois), Robin Wilson, Mable Mulanya (Integrated Breeding Platform), Ramni Jamnadass, Prasad Hendre (ICRAF), and Damaris Odeny (ICRISAT) and were complemented with several discussions at local breeding programs such as CIMMYT. Local support for the AfPBA was provided by World Agroforestry and director Tony Simons with logistical support from Imelda Ingumba and Mehmood Hassan. Logistical support at the SBC was provided by Julie Tillman, Rebeca Madrigal, Susan DiTomaso and Kelsey Maher.

The AfPBA aims to train 150 of the top African plant breeders in the latest plant breeding strategies, including population improvement, quantitative genetics, selection theory, objective phenotyping and application of genomics to plant breeding. The goal is to enhance the ability of Africans to provide nutritious food to reduce stunting due to malnutrition. This program was organized in collaboration with The African Union New Partnership for Africa's Development (NEPAD) Agency and the African Orphan Crops Consortium. The AfPBA gratefully received financial support from Mars, Incorporated for this class. The graduates created a video that can be viewed @ www.pba.ucdavis.edu.

In Memoriam

In March 2019, Dr. Kodjo Glato from the University of Lome in Togo passed away in a airline crash while en route to training in Nairobi. He was a student in AfPBA Class IV. Dr. Galto was the first member of his family to pursue higher education. As a dedication, a tree was planted in his name at World Agroforestry. The AfPBA Class will always remember our colleague.

In 2019, we also lost a good friend and colleague, Dr. Mehmood Hassan. Mehmood was the lead for capacity development at World Agroforestry in Nairobi including local logistics, accommodation and travel for all AfPBA students from the very beginning. Mehmood was one of those people who strived to make everyone's life better every day by simply saying hello and being genuinely interested in knowing people. He touched so many of us personally and professionally on a local and global scale. We are fortunate to have known Mehmood for 8 years through his work with the African Plant Breeding Academy.
Africa Plant Breeding Academy Class IV graduates

Abimbola Oluwaranti, Obafemi Awolowo University, Nigeria
Abiola Amao, Forestry Research Institute of Nigeria, Jericho hills Ibadan, Nigeria
Ahmed Mohamed Abdelmoghny, Agricultural Research Center, Egypt
Aleck Kondwakwendla, Crop Breeding Institute, Zimbabwe
Alexander Kena, Kwame Nkrumah University of Science and Technology, Ghana
Amade Muitia, Mozambique Agricultural Research Institute, Mozambique
Amelework Beyene Assefa, Agricultural Research Council, South Africa
Eric Agoyi, Non-Timber Forest Products & Orphan Crops unit, University of Abomey-Calavi, Benin
Inge Gazendam, Agricultural Research Council, Vegetable and Ornamental Plants, South Africa
Isaac Onziga Dramadri, Makerere University Regional Center for Crop Improvement, Uganda
Isata Kamanda, Sierra Leone Agricultural Research Institute, Sierra Leone
Jane Mbugua, Kenya Agricultural and Livestock Research Organization, Kenya
John Saviour Yaw Eleblu, West Africa Centre for Crop Improvement, University of Ghana, Ghana
Kesbell Kaonga, Department of Agriculture Research Services, Ministry of Agriculture, Malawi
Kouadio Nasser Yao, Biosciences Eastern and Central Africa-International Livestock Research Institute Hub, Kenya
Kumba Yannah Karim, Sierra Leone Agricultural Research Institute, Njala Agricultural Research Center, Sierra Leone
Liliane Tandzi Ngoune, University of Fort Hare/Institute of Agricultural Research for Development, Cameroon
Lloyd Mbulwe, Zambia Agriculture Research Institute, Zambia
Matilda Bissah, Plant Genetic Resources Research Institute, Council for Scientific and Industrial Research, Ghana
Maxwell Okoye, Nigerian Institute for Oil Palm Research, Nigeria
Mizan Tesfay Abraha, Tigray Agricultural Research Institute, Ethiopia
Moumouni Konate, Institute of Environment and Agriculture Research, Burkina Faso
Mounira Elbaz, CRRHAB, Regional Research Centre on Horticulture and Organic Agriculture, Tunisia
Patrick Ongom, International Institute of Tropical Agriculture, Nigeria
Pavithravani Venkataramana, The Nelson Mandela African Institution of Science and Technology, Tanzania
Safiatou Sangare, Institut d’Economie Rurale, Mali
Samia Lotfy, National Institute for Agricultural Research, Morocco
Santatra Ravelomanantsosa, Cenraderu-Fofifa, Madagascar
Seyni Boureima, University of Maradi, Niger
Tesfahun Alemu Setotaw, Kulumsa Agricultural Research Center, Ethiopian Institute of Agricultural Research, Ethiopia
Viviane Raharinivo, National Center of Applied Research for Rural Development, Department of Rice Research, Madagascar
Walter Ajambang Nchu, Institute of Agricultural Research for Development, Cameroon
African Orphan Crops Consortium

The African Orphan Crops Consortium’s (AOCC, www.africanorphancrops.org) objectives are to improve the nutrition, productivity and climatic adaptability of food crops important to Africa’s diet to decrease the stunting due to malnutrition that is widespread (22-42%) among the continent’s rural children. This is being achieved through providing genomic sequence and diversity analysis for 101 food crop species. In 2019, AOCC released three genomes, breadfruit (*Artocarpus altilis*), jackfruit (*Artocarpus heterophyllus*) and African eggplant (*Solanum aethiopicum*) supplementing the five released in 2018. An additional 18 are scheduled to be released in the next year with 28 more in progress. The impact is delivered by varieties (37 so far) bred by AfPBA graduates using the latest technologies and strategies provided by AOCC partners and the AfPBA. Graduates have published more than 171 peer-reviewed articles since they attended AfPBA and are transferring knowledge to students in their home institutions. For the 2019 progress, see publication by Hendre *et al.* (page 26).

**African Plant Breeding Academy graduates establish African Plant Breeders Association**

African Plant Breeding Academy (AfPBA) Class II cohorts, Enoch Achigan Dako (Benin) and Julia Sibiya (South Africa), conceived the idea of a Community of Practice for ongoing professional development of scientists in crop improvement after participating in the intensive capacity-building program. They were joined by other AfPBA cohorts Agyemang Danquah (Ghana) and Beatrice Elohor (Ghana) and other colleagues in establishing the African Plant Breeders Association (APBA), working together with Dr. Eric Danquah (Director of Western Agricultural Centre for Crop Improvement, Ghana). The APBA launched its inaugural biennial conference on Oct 25-27, 2019, in Accra, Ghana, attracting over 420 attendees from 38 countries. The APBA is a forum through which members can share research findings, spawn collaborations and further educational quality in plant breeding. Allen Van Deynze, Rita Mumm (AfPBA director) and Howard-Yana Shapiro (AOCC) were invited speakers. Several AOCC partners also conducted workshops. The next meeting is slated to be held at Makerere University in Uganda in 2021.
SBC Educational Courses

The technical nature of plant breeding and seed production requires a highly educated workforce. A key goal of the SBC has been to provide ongoing education for professionals in the seed industry.

Seed Production

This course is designed to enhance participants’ knowledge of the underlying biology of seed production and the key roles of bees and other insect pollinators, how to manage seed crops from agronomic, quality control, and genetic integrity standpoints, and how to meet new challenges through seed production research.

This year, 61 participants represented 14 countries and over 40 companies with regional, national and international reach. Course instructors included Mike Pereira from the seed industry, Kent Bradford and Rale Gjuric from the UC Davis Seed Biotechnology Center, and Greg Welbaum from Virginia Tech University, as well as several guest speakers from both UC Davis and the industry.
Seed Business 101

The one-week Seed Business 101SM program exposes participants to the five functional areas of a seed company: research and development, production, operations, sales and marketing, and administration.

Content is delivered with an interactive approach by creating a virtual seed company and examining case studies for each functional area. Those new to the seed industry are provided with a broad understanding of the major aspects of a seed company’s operations and cross-departmental knowledge of best practices for profitability.

Two distinct programs are offered, one focusing on field crops and the other on horticultural crops, and are taught by widely respected industry executives with additional help of experts participating as guest speakers.

Course instructors included Tom Francis, Craig Newman and Dave Westphal (Field Crops); and Mike Pereira, Maurice Smith and Pieter Vandenberg (Horticultural Crops). In 2019, 19 participants attended Field Crops and 29 attended Horticultural Crops.

More than 601 participants from a wide range of companies with regional, national and international reach have completed this course since its inception in 2010.
Hemp Breeding and Seed Production

This year, the SBC offered its first course in Hemp Breeding and Seed Production. The course was designed to enhance the knowledge of professionals working on hemp improvement and propagation. Topics included flowering, pollination, seed development, harvesting and certification. Course participants also learned about hemp genomics, genetics, sex expression, types of cultivars with corresponding breeding schemes and intellectual property protection options.

The course was the most attended course the SBC has offered with over 165 participants from 6 countries. Instructors included experts from both industry and academia: Kent Bradford, Rale Gjuric, Allen Van Deynze, Amanda Vondras, John Yoder (all UC Davis), John Palmer (California Crop Improvement Association, UC Davis). Larry Smart (Cornell University), K. Bear Reel (Charlotte's Web, Inc.), Nicholas Stromberg (Beacon Hemp), and Chris Holly and Daniel Knauss (both Cooley LLP).
Seed Central

UC Davis is a world leader in seed, plant and agricultural sciences. While the influence of UC Davis extends throughout the USA and far beyond, more than 100 seed and seed-related companies clustered near UC Davis benefit greatly from its proximity. Established in 2010 as an initiative of the UC Davis SBC and SeedQuest, Seed Central (SC) facilitates communication, networking and research collaboration between UC Davis and the surrounding seed and ag biotech industries. Forty seed, agricultural biotechnology and food companies are members of SC, including many that are headquartered overseas. Seed Central offers regular networking events with featured guest speakers in Davis (nine per year) and Salinas (two per year). Since SC’s creation in 2010, attendance at these events has continued to grow, with a total of over 3,000 participants from over 350 companies and organizations from California, the U.S. and overseas having attended these events.

Seed Central Student Programs

In addition to connecting campus and industry scientists, Seed Central focuses on connecting UC Davis students with mentors and employers by offering a range of activities enabling students to be engaged frequently and regularly with the seed, agbiotech and food industries. Students can attend monthly networking events in Davis and Salinas, professional development workshops, and, in collaboration with the Plant Breeding Center, field trips to companies in the region. Seed Central also offers students a pairing and mentorship program connecting them with industry professionals and offering opportunities to shadow industry researchers for a day, dinners with research executives and HR managers, and assistance in finding internships (including internationally) and permanent employment.

Seed Central Highlights

The Networking Tech Showcase for seed, ag and food companies: startups, early stage and beyond

In January, Seed Central hosted its annual Networking Tech Showcase. Industry representatives from more than 40 companies participated and engaged in discussion and brainstorming with educators and students about the different stages of company growth. The showcase was the most successful to date.
The "Job Panorama" in a seed company

Seed Central hosted this special event in collaboration with HM.Clause in April. Students were invited to discover the wide range of exciting, high-tech jobs that make up a seed company. We "X-rayed" HM.Clause's workforce to understand what sort of team it takes to go from research through production, supply chain, operations, sales and marketing, all the way to the market. We heard from a wide range of employees about their respective jobs.

Students had the opportunity to be paired with each of these seed professionals prior to the event and to shadow them on the job afterwards. In addition, the event also featured startup entrepreneurs: Jeremy Warren, Astrona Biotechnologies, Dark Heart Industries and Sesan Ajina, InSight Labs.

Seed Central hosts the California Seed Association's Fall Student Tour for lunch and a networking career fair

In October, Seed Central collaborated with the California Seed Association to host a career fair. The career fair featured 11 panelists from Seed Central member companies with 70 student participants from Chico State, UC Davis, Fresno State, Cal-Poly, CSU Monterey Bay and Hartnell College.
Collaboration for Plant Pathogen Strain Identification (CPPSI)

CPPSI is a science-based, vegetable seed industry-sponsored initiative to standardize the identification of plant pathogen strains and races based on sets of host differentials, reference plant pathogen strains and informative white papers, collectively referred to as Reference Materials.

CPPSI priorities are to recruit members, develop new sets of plant pathogen strain differentiating Reference Materials and collaborate with similar organizations to ensure the consistent naming of plant pathogens on a global scale. The CPPSI working group consists of representatives from sponsoring companies who meet monthly by conference call to discuss Reference Materials in development, ISF initiatives and projects, plan ring tests, review articles and white papers and any issues that come up in our work.

CPPSI Services were launched on www.CPPSI.org in July. CPPSI can assemble and distribute Reference Materials ordered on the CPPSI website, www.cppsi.org. The service is free to CPPSI members and available to non-members for a nominal fee.

In collaboration with the UC Davis Strategic Communications team, a CPPSI marketing plan was developed to promote CPPSI membership and services. Brochures, cards, banner ads and a promotional video have been developed to reach out to industry, government and academic scientists. The CPPSI website was also updated and expanded to promote as well as inform stakeholders about CPPSI services and Reference Materials. The new website will be launched in May 2020. These marketing efforts also fulfill the outreach requirement for the CDFA specialty crops block grant awarded to CPPSI in 2017. The current CPPSI website remains an active portal for information, ordering CPPSI services as well as Reference Materials (host sets).

Number of Host Sets Distributed from 2010* - December 2019

<table>
<thead>
<tr>
<th>Year</th>
<th>Host Sets Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
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</tr>
<tr>
<td>2011</td>
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</tr>
<tr>
<td>2019</td>
<td>73</td>
</tr>
<tr>
<td>TOTAL</td>
<td>906</td>
</tr>
</tbody>
</table>

*2010 - 2012: CPPSI housed on International Seed Federation web site  
**2013: Independent CPPSI domain established  
***2015 - present: CPPSI domain hosted by the University of California, Davis
CPPSI distributes reference materials for tomato ToMV, spinach Downy mildew, melon Fusarium wilt, pepper Bacterial spot and lettuce Downy mildew via our website www.cppsi.org. Since establishing a base of operations at the UC Davis Seed Biotechnology Center in July 2015, CPPSI has aimed to initiate a new round of Reference Material development each year. It takes approximately 6 – 9 months to assemble and propose each round of disease systems to the CPPSI Advisory Council. Each approved disease system is assigned a lead from the CPPSI WG to assemble the Reference Materials and help in the assembly of photos and background information for the white paper. Depending on the complexity of the disease system, it takes 2–3 years to develop and distribute reference materials. Reference Materials for pepper and tomato TSWV were launched on the CPPSI website in December 2019.

CPPSI collaborates with members of the International Seed Federation Disease Resistance Terminology working group (ISF DRT WG) to promote consistent strain naming and identification on a global scale. The ISF DRT WG is made up of scientists from Naktuinbouw, GEVES-MATREF, Plantum, the European Seed Association, the Asia-Pacific Seed Association (APSA) and CPPSI. The group works together to develop and update differential host tables for vegetable disease systems against which claims of disease resistance are made on a global scale. Over the past year, differential tables for 20 disease systems were created and/or updated. Several are still in development. This is an important project to ensure the created and revised reference pathogen races/strains and differentiating hosts are equivalent to those used in developing and launching CPPSI Reference Materials. They are now posted on the ISF website @ www.worldseed.org

For the past three years, CPPSI has collaborated with representatives from GEVES-MATREF, Plantum, the European Seed Association and Naktuinbouw in a project called Harmores 3 (H3). Protocols and Reference Materials for use in new variety registration in Europe were developed for melon Fusarium wilt, tomato Fusarium wilt and Root knot nematodes and pea Powdery mildew. Reference Materials for melon Powdery mildew are in the final stages of development. These disease systems corresponded with the CPPSI Round 3 Reference Materials development. H3 was an important project for CPPSI participation to ensure the protocols, strains and differentiating hosts are the same as or equivalent to those used in developing and launching CPPSI Reference Materials.

An article about CPPSI was published in the APSA Seed Journal that was distributed during the 26th Asian Seed Congress in Malaysia in November 2019. Szabolcs Ruthner of ISF participated in these meetings and began the discussions about consistent strain naming with APSA members. CPPSI was invited to participate in the 2020 Congress. Members of CPPSI, GEVES-MATREF and ISF have collectively written papers on ISF guidelines for consistent strain naming presented this year at APS, Eucarpia, Plantum and ESA sponsored meetings.
1999-2000

- SBC founded with support from Dean Neil Van Alen and Associate Dean Alan Bennett with assistance of Mike Campbell (UC Davis CAES).
- CCIA (Chip Sundstrom) and CSA (Rich Matteis) supported creation of SBC.
- Kent Bradford appointed director and Sue DiTomaso hired as program manager.
- Fund campaign initiated for building to house SBC.
-Basics of Plant Biotechnology for Business and Seed Biology, Production & Quality course offered.
- CA Seed Advisory Board began providing operating funds for SBC.
- SBC Advisory Council established to offer strategic vision and advice.

2001

- Construction began on Plant Reproductive Biology (PRB) building (future home of SBC).
- SBC presented on biotechnology for U.S. State Department for European politicians.
- SBC hosted Western Regional Seed Physiology Research Group.
- SBC organized workshop on Crop Biotechnology: Food and Pharmaceutical Program.
- Research published on gene expression in germinating tomato seeds.

2002

- Allen Van Deynze joined SBC as Biotechnology Specialist and director of research.
- SBC and UC Agricultural Issues Center sponsored workshop on Biotechnology for Horticultural Crops.
- Ralph M. Parsons Foundation Plant Transformation Facility opened at UC Davis with funding secured by SBC.
- SBC raised $1.5 million for PRB building campaign.
- SBC presented Crop Improvement Using Biotechnology at seven CDFA Team Seed workshops.
- Research published on a hydrothermal time model for seed germination.

2003

- SBC organized Identity Preservation in Crop Production & Marketing workshop.
- SBC hosted California Plant Health Association Workshop for CA legislative members.
- SBC director Kent Bradford elected a Fellow of the American Association for the Advancement of Science and received Career Seed Award from Crop Science Society of America.
- Research published on hormonal regulation of SNP1 kinase expression in tomato seeds.

2004

- Dedication held for PRB building that houses SBC.
- Public Intellectual Property Resource for Agriculture (PIPPRA) joined SBC in the PRB with Alan Bennett as director.
- Breeding with Molecular Markers course offered.
- SBC provided information for ballot measure regarding regulation of genetically engineered organisms.
- SBC co-edits special issue of California Agriculture on Challenges and Opportunities for Horticultural Biotechnology.

2010

- Rale Gjuric joined SBC as director of education.
- SBC offered Seed Business 101 with instructors Maurice Smith, Gary Whiteaker, Pieter Vandenbeng, Dave Westphal and Tom Francis.
- SBC collaborated to create a new online plant breeding and genomics community housed on eXtension.
- Research published on:
  - Special journal issue on Seed Biology: From Model Systems to Crop Improvement.
  - A gene that prevents lettuce seed germination at high temperature.
  - Microarray analysis of a recombinant inbred line population in lettuce.
  - Regulatory bottlenecks for biotech specialty crops.

2011

- Allen Van Deynze and UC Davis Student Farm hosted a program reaching more than 1,600 K-12 students.
- Gabe Patin retired from the Advisory Council after many years of support for the SBC.
- Seed Central organized three Forums on seed biotechnology.
- Research published on:
  - De novo assembly and characterization of the carrot transcriptome.
  - Honey bee foraging range in alfalfa seed production fields.

2012

- Howard-Yana Shapiro established African Orphan Crops Consortium (AOCC) and recruited SBC to offer African Plant Breeding Academy.
- Seed Central hosted monthly networking Forums and created Plant and Seed Sciences Partnership Program (PSSPP).
- Sally Mohr joined SBC as a program manager.
- Research published on:
  - Using desiccants to dry and preserve seeds in humid climates.
  - A transcription factor regulating uniform ripening of tomato fruit.

2013

- African Plant Breeding Academy hosted first class in Nairobi with Rita Mumm as director.
- SBC offered Program Management for Plant Breeders.
- Kitty Schlosser joined SBC as a program manager.
- Research published on:
  - Single-seed respiration: A new method to assess seed quality.
  - Using GeneChip to characterize pepper genetic diversity.

2014

- AOCC opened genomics laboratory at ICRAF in Nairobi, Kenya with leadership by Allen Van Deynze.
- Francois Kern received CAES Award of Distinction.
- The Plant Breeding Center (PBC) established in Department of Plant Sciences with Charles Brummer as director, Allen Van Deynze as associate director and Amanda Pietras (Salichae) as program manager.
- HM Clausl initiated the Kent J. Bradford Endowed Chair in Seed Science.
- Research published on:
  - Gene identified that regulates natural variation in pepper fruit color.
  - Genome sequence of hot pepper.
SBC joined the newly established Plant Sciences Department.

SBC joined the Specialty Crops Regulatory Initiative coalition.

SBC participated in Public Research and Regulations Initiative on the international level.

Research published on:
- Regulating transgenic crops sensibly.
- Pollen-mediated gene flow in California cotton.

SBC offers the first Plant Breeding Academy (PBA) in Davis with instructors Doug Shaw, Larry Teuber, Todd Wehner, Allen Van Deynze, and Kent Bradford.

Tanya Meyer & Cathy Glaeser hired as program representatives.

Allen Van Deynze represented UC Davis on multi-state USDA Plant Breeding Coordinating Committee.

Kent Bradford appointed to Plant Variety Protection Advisory Board.

Researchers developed high-throughput DNA extraction from seeds; published on economics of horticultural biotechnology.

Michael Campbell joined SBC as executive director.

SBC hosted international symposium on Translational Seed Biology.


Kent Bradford received CA&ES Award of Distinction.

Research published on:
- Compliance costs for regulatory approval of new biotech crops.
- Gene flow in biotech crops.
- Diversity in conserved genes in tomato.

SBC hosted Chilean Ambassador Mariana Fernandez and U.S. Ambassador to Chile Paul Simons as Chilean President Michelle Bachelet and Governor Arnold Schwarzenegger create agreements renewing the Chile-California partnership to support plant breeding.

The first PBA class graduated.

UC Discovery Fellow Jamie Miller (Zaitlin) joined SBC as assistant director. Jeannette Martinis as program manager and Diane Nation as communications lead.

Research published on:
- 100 Years of Breeding: A History of Plant Breeding at UC Davis.

SBC organized first SolCAP workshop on tomato and potato breeding.

Collaboration for Plant Pathogen Strain Identification (CPPSI) established at SBC in cooperation with American Seed Trade Association and Phyllis Himmel as director.

Seed Central launched Discover Series.

Cristobal Heitmann joined SBC and worked on maize project; Rebecca Madrigal and Julie Tillman joined as program managers.

Research published on:
- Applying developmental threshold models to evolutionary ecology.
- High-density mapping of intraspecific and interspecific populations of cotton.

Seed Central hosted Women in the Seed Industry.

Research published on:
- Single-seed oxygen consumption measurements link respiration and germination rates.
- First genome sequence of coffee (Coffee arabica).
- Lettuce seed germination mutants identified by bulked segregant analysis and whole genome sequencing.
- Regulation of both seed dormancy and flowering time through microRNA pathways.
- Carrot genome assembly and new insights into carotenoid accumulation.

SBC hosted its 20th Anniversary Symposium.

Allen Van Deynze received Excellence in Research Award from UC Davis Academic Federation and became SBC director.

SBC offered Hemp Breeding and Seed Production course.

Rale Gjuric, SBC director of education, named one of the most influential people in the seed industry.

SBC offered Seed Production course.

SBC founding father Gabe Patin received CA&ES Award of Distinction.

Research published on:
- A roadmap for breeding orphan leafy vegetable species.
- QTL controlling fruit size and other horticultural traits in bell pepper.

SBC hosted its 20th Anniversary Symposium.

- Allen Van Deynze received Excellence in Research Award from UC Davis Academic Federation and became SBC director.
- SBC offered Hemp Breeding and Seed Production course.

- Kelsey Maher joined SBC as a program manager.
- Kent Bradford and Sue D’Tomasso retired from UC Davis.
- Research published on:
  - Genetic analysis of resistance to multiple isolates of Phytophthora capsici.
  - ACC: status of developing genomic resources.
  - Sequencing-based bin map construction for a tomato mapping population.
  - A survey of mixed Begomovirus infection in Solanaceae.
OUTREACH AND PUBLIC SERVICE

UC Davis World Food Center

The UC Davis World Food Center (WFC) serves as a portal for access by the public and industry to the vast food-related resources at UC Davis. Kent Bradford was appointed interim director of the WFC in 2017 in addition to his role as director of the SBC. During 2018, he worked with program manager Kaylee D’Amico and a faculty committee to reinvigorate this center after its transfer to the College of Agricultural and Environmental Sciences.

In January 2019, Ermias Kebreab assumed the role of associate dean of Global Engagement and Director of the World Food Center. A distinguished scholar and skilled administrator with extensive international experience, Dr. Kebreab has conducted extensive research in developing strategies for using feed additives to reduce methane emissions from livestock. Kent continued as the associate director until his retirement in June 2019, and was recalled to continue that role part-time until June 2020.

During 2019, the WFC developed a strategic plan (https://worldfoodcenter.ucdavis.edu/strategic-plan), consulting with over 100 campus leaders through showcases and meetings. This plan envisions UC Davis as a global leader in developing solutions for providing safe, nutritious and affordable food for Californians, the nation and the world. Going forward, the WFC will focus on three main priorities: to Convene, Connect and Communicate. To this end, the WFC co-sponsored two workshops in May 2019: Aligning the Food System for Improved Nutrition: A Focus on Animal Source Foods, and Food Safety Considerations for Developing Food Waste Solutions. In September, it co-sponsored a UC Network program on Child Health, Poverty, and Public Policy and a working group on Developing an Agrifoods System Blueprint for California. The WFC also collaborated with the John Muir Institute of the Environment to host a symposium in November called Dialogues and Discourse in Science and Society: Science and the Social License. This one-day conference, supported by a grant from the National Institute of Food and Agriculture, convened a diverse group of experts to discuss how to bridge the gap between scientific innovation and public acceptance, using climate change and genetic engineering as primary examples. The conference featured esteemed speakers from around the country and key California and UC leaders, including Katherine Ross (CA Secretary of Agriculture), Janet Napolitano (UC President) and Gary May (UC Davis Chancellor). Speakers and participants explored why public opinion often diverges from scientific consensus, and discussed what scientists and scientific institutions can do to counter misinformation.

SBC Awards and Appointments

The SBC director of education, Rale Gjuric, was appointed to the Plant Breeding Committee of the Canadian Seed Growers’ Association. This committee deals with issues of seed certification, including review and recognition of candidates for the status of Plant Breeder with CSGA.

In May, UC Davis granted Allen the 2019 Excellence in Research Award. Van Deynze has conducted groundbreaking research in Mexico and in Africa and is the lead author of a landmark study that determined how indigenous varieties of maize in the Sierra Mixe region of Mexico are able to fix nitrogen from the atmosphere, instead of requiring synthetic fertilizers. He was also recognized for his work as the scientific director of the African Orphan Crops Consortium.
OUTREACH AND PUBLIC SERVICE

UC Davis Plant Breeding Center

The Plant Breeding Center continued organizing and promoting plant breeding activities on campus in 2019. In June, the PBC sponsored a conference on “Breeding Crops for Enhanced Food Safety” with support from the National Institute of Food and Agriculture and Department of Plant Sciences. Over 80 scientists participated in the conference, which began a discussion on the problem of food safety and ways plant breeding and genetics could help minimize or prevent safety concerns with our food. A white paper authored by Maeli Melotto, Michelle Jay-Russell (UC Davis) and Allen Van Deynze was published to summarize the results for government agencies.

The PBC held another successful retreat in December 2019 at the UC Davis Bodega Bay Marine Lab, with about 75 attendees. The retreat included scientists from UC Riverside, UC Berkeley, and Cal Poly Pomona, in addition to UC Davis. The retreat theme was “Revolutionary Breeding,” kicked off with a forward-looking talk on where plant breeding will go in the future by Richard Michelmore (UC Davis). The retreat offers an excellent opportunity for networking among public plant breeding faculty, staff, postdocs, graduate students, and undergraduate students throughout California. We included a poster session this year, with prizes for the top two presenters.

The PBC was actively involved in revising the undergraduate Plant Breeding track in our Plant Sciences major, part of the departmental overhaul of our undergraduate program. The revised major will hopefully be more visible and attractive to incoming students, and the Plant Breeding track offers students a straightforward path to working in the field, either directly or as a stepping stone into graduate school.

We sponsored a number of seminars throughout the year, including a talk from Hannes Dempewolf, the head of global initiatives of the Crop Trust; a reading with Bob Quinn and Liz Carlisle from their new book Grain by Grain; and a discussion with international growers of teff—an African grain—which resulted in a series of field trials on the UC Davis campus. In addition, monthly field trips, now held in conjunction with Seed Central and Francois Korn, visited local breeding and crop improvement businesses.

The university’s Germplasm and Cultivar Release Committee, chaired by PBC director Brummer approved the release of five new strawberry cultivars from Steve Knapp’s program, five Pierce’s disease-resistant grapevine cultivars from Andy Walker’s program, a new wheat cultivar, UC-Amarillo, from Jorge Dubcovsky’s program, and a new barley cultivar by Lynn Gallagher.

The Student Collaborative for Organic Plant Breeding Education (SCOPE) program continued refining and expanding its student-led breeding programs in tomato, pepper, common bean, and wheat. The bean project released six new heirloom-type beans that incorporate Bean Common Mosaic Virus resistance. These are public releases and available to the bean-growing community. Experimental peppers and tomatoes are moving toward release in the next year or two.

Plant breeding at UC Davis is alive and well, and we are looking forward to a successful 2020, despite the current COVID-19 disruption!

The PBC’s website can be found at www.plantbreeding.ucdavis.edu.

Seed Biotechnology Center, UC Davis
OUTREACH AND PUBLIC SERVICE

The Kent J. Bradford Endowment

The Kent J. Bradford Endowed Chair in Seed Science will provide support for a faculty member at UC Davis who would be focused on seed biology and technology and potentially serve as the director of the Seed Biotechnology Center. The endowment will ensure that the seed industry's needs for academic research, education and public service can continue to be met in perpetuity. For more information or to contribute to our goal, contact Melissa Haworth at mdhaworth@ucdavis.edu.

SBC Presentations

Each year the SBC staff makes numerous presentations for diverse groups to discuss various topics related to seeds, biotechnology and agricultural research.

Presentations: Kent Bradford

- Bradford, K.J. Developing the UC Davis Seed Biotechnology Center: What comes next? Centro Investigaciones para Grano y Semillas (CIGRAS), University of Costa Rica, San Jose, Costa Rica and participation in Strategic Planning process, June 3-7, 2019.
- Bradford, K.J. The Field Man (or Woman) of the Future. ANPROS (Chilean Seed Association) annual meeting, Santiago, Chile, August 20, 2019.
- Bradford, K.J. The past is prologue. Seed Central, UC Davis, September 12, 2019.
- Bradford, K.J. Implementing the Dry Chain to reduce food waste and toxicity. Food Security and Food Innovation Workshop, UC Davis, October 8, 2019.
Presentations: Allen Van Deynze

- Van Deynze, A. Nitrogen fixation in a landrace of maize is supported by a mucilage-associated diazotrophic microbiota. Jan 15, San Diego; Feb. 13, Iowa State University; Feb 21, Michigan State University; Oct 2, University of Georgia.
- Van Deynze, A. Gene Editing Systems in Plants. UC Davis College of Agricultural and Environmental Sciences Dean’s Council. April 25, 2019.
- Van Deynze, A. Application of Technology to Hemp Breeding. UC Davis. October 29, 2019.
Seed Physiology and Technology

Indicators of seed heterogeneity

Seed performance expectations for uniform germination and seedling emergence continue to increase. Postharvest conditioning technologies to detect heterogeneity in seed lots and remove lower quality seeds could be used to upgrade diverse seed lots. Pedro Bello in the Bradford Lab is testing whether uniformity and other quality characteristics can be detected using non-destructive spectral analysis methods. For example, the CF Mobile® instrument can measure chlorophyll content of individual seeds, an indicator of seed maturity. The Videometer® can collect and analyze images of individual seeds in multiple wavelengths to detect specific microorganisms or physical variation or defects. In collaboration with several seed companies, we are imaging seed samples by these methods and subsequently assessing their germination characteristics, including through single-seed respiration measurements. This allows spectroscopically detectable characteristics of individual seeds to be correlated to their respiration and germination performance and uniformity. We are analyzing seed lots sorted by size or density, or having physiological defects such as seedling blindness, in this way to determine whether it would be possible to identify such variants and therefore upgrade seed lots for increased uniformity and performance.

Simplifying application of seed germination models

The Bradford Lab has been developing and utilizing population-based threshold (PBT) modeling approaches to describe seed germination characteristics for 30 years. Various versions of these models have been applied to a wide range of factors that influence seed germination, including temperature, water potential, hormones, priming, oxygen and aging. In this model, individual seeds vary in their sensitivities to various factors, and characterizing the distribution of these thresholds enables quantification and prediction of the germination behavior of seed populations. While we have previously developed Excel spreadsheets to facilitate fitting of these models to germination data, they have been difficult for some potential users to apply in practice. As part of his M.Sc. thesis, Pedro Bello is developing a suite of scripts in the R programming language to enable broader use of these tools for characterizing seed performance. The Western Regional Seed Physiology Research Group supported this project.

Applying face-recognition technology to seeds

It is now evident that digital imaging, combined with artificial intelligence analysis methods, can detect and discriminate among facial traits to identify specific people. What if this technology were applied to seeds? Could underlying genetic traits be detected? These questions are being pursued by Seed-X (seed-x.com), an Israeli company offering genetic analysis services based upon digital images of seeds. In some cases, this analysis can identify whether a seed has inherited a specific gene based on the seed phenotype. Seed-X is collaborating with the Bradford Lab by loaning us one of their data acquisition instruments. We are testing the extent to which underlying genetic differences can be detected in seed phenotypes of segregating recombinant inbred line populations of lettuce. The instrument currently is available for use by seed companies and faculty members who would like to test its capabilities with their own breeding lines or populations or for seed quality assessment.

Intraspecific trait variation may contribute to plant invasions

Variation in phenotypic traits within natural populations of a given species (i.e., intraspecific trait variation) is the basic source for selection and can have significant ecological consequences. Greater variation may increase a population’s niche breath and benefit interspecies competition under a resource-limited environment, thus affecting the ability of a species to move into novel habitats. Former PhD student in the Bradford Lab, Shuangshuang Liu, conducted a study of the invasion trends for an introduced annual grass (*Brachypodium hybridum*) in California (see Publications on page 26). Field and common garden studies suggested that populations exhibiting greater trait variation (including seed mass) in response to irrigation could contribute to the progressive spread of this species to drier and warmer climates. Thus, not only average phenotype, but also the variation in individual plant/seed traits can contribute to adaptation and competitiveness of invasive species. The China Scholarship Council and the Department of Plant Sciences, UC Davis, supported this research.
Hydrothermal sensitivities of seed populations underlie seed dormancy patterns

Plant germination ecology involves continuous interactions between changing environmental conditions and the sensitivity of seed populations to respond to those conditions at a given time. Ecologically meaningful parameters characterizing germination capacity (or dormancy) can advance our understanding of the evolution of germination strategies within plant communities. Population-based threshold (PBT) models of seed germination enable quantification of patterns of germination timing using parameters based on mechanistic assumptions about the underlying germination physiology. Shuangshuang Liu, former PhD student in the Bradford Lab, worked with Zhenying Huang and Lawrence Venable at the University of Arizona to apply the hydrothermal time (HTT) model, a type of PBT model that integrates environmental temperature and water availability, to study germination physiology in a guild of coexisting desert annual species (see Publications on page 26). Seeds were after-ripened by dry storage under different conditions and durations and germinated in the laboratory under controlled temperature and water potential conditions. The loss of dormancy during after-ripening was described well by the HTT model across all species. Predictions based on variation in HTT model parameters among twelve coexisting species correlated with 25-yr observations of germination dates and percentages for the same species in natural field conditions. Seed dormancy and germination strategies, which are significant contributors to long-term species demographics under natural conditions, can be represented by readily measurable functional traits underlying variation in germination phenologies. The National Science Foundation and the China Scholarship Council supported this research.

Seed and Commodity Storage

The Dry Chain: Seed drying and storage strategies for humid regions

Seeds lose viability rapidly in high humidity and warm temperatures, which prevail throughout the humid tropics. A novel method for seed drying using desiccant Drying Beads® (from Rhino Research) enables drying of seeds to safe storage moisture contents even in rainy climates (www.dryingbeads.org). When combined with hermetic storage containers, the seeds also are protected from damage due to molds, insects and rodents. We call this combination of drying upon harvest and subsequent waterproof packaging the “Dry Chain”, in analogy to the “Cold Chain” of continuous refrigerated storage used to preserve fresh produce (www.drychain.org). Drying Beads and other associated equipment are now being supplied in the Western Hemisphere through Dry Chain America based in Longmont, Colorado. We also continue to collaborate with the USAID Horticulture Innovation Laboratory at UC Davis to distribute DryCards®, simple relative humidity indicators that can be used to determine whether seeds are sufficiently dry for safe storage.

The Bradford Lab is cooperating with various groups to extend these technologies to multiple countries. For example, we collaborated with Denise Costich, head of germplasm preservation at CIMMYT in Mexico, in a project to utilize Dry Chain methods in community-based maize seed preservation programs in Guatemala. That project was highly successful in demonstrating the advantage of seed drying followed by storage in hermetic containers for preserving seed viability. In another project in India, the Vivia Foundation, Renuka Bio Farms, Grameena Vikas Samithi (a United Nations certified NGO), Telangana State Seed Certification Authority, and International Crop Research for the Semi-Arid Tropics (ICRISAT) collaborated to test the Dry Chain for storage of peanuts to preserve quality and prevent aflatoxin accumulation. The group also included Vasudhaika Software Pvt Ltd, who developed a mobile platform (Kalgudi) for field data collection, documentation and research analysis. The results demonstrated that Dry Chain storage systems preserved quality better than standard storage in porous bags, which exposes the peanuts to ambient high relative humidity. Mars, Incorporated provided partial funding for both of these projects.
Genetics, Genomics and Breeding

Carrot: Bolting in carrot is complex

The SBC is working with Phil Simon (USDA/ARS, Madison, WI) on a multi-year grant to discover and characterize carrot quality; resistance to Alternaria, Pythium and nematodes; tolerance to drought; and resistance to bolting. In the 3rd year of this 5-year project, Theresa Hill, Armando Garcia-Llanos, Shiyu Chen and Allen Van Deynze now have 3 years’ data on bolting of 675 diverse carrot lines from 5 locations including Hancock, WI and El Centro, Riverside and Coachella, CA in fall and spring plantings. As part of this project, mapping populations and a large diversity set of 800 lines have been sequenced to decipher the genetic basis of the traits and simultaneously breed favorable alleles into adapted germplasm. From the sequence analysis, over 500,000 DNA markers were used to identify genetic loci linked to bolting and to classify germplasm. There is a clear divide between lines from eastern and western hemisphere countries. Data from summer environments were highly correlated with large genotype x environment interactions, indicating complex genetic control of bolting in carrot. This project also supports the UC Davis Student Farm and UC ANR Desert Research Center (El Centro, CA) to introduce/recruit K-12 students using carrot genetic diversity as a model. Over 900 children have had experiential learning with carrots in breeding diversity modules. Collaborating institutions include USDA/ARS, University of Wisconsin, UC Riverside, University of Washington and Cornell University. This program is funded by the USDA Specialty Crops Research Initiative.

Celery: Defining the celery genome

Celery is an important vegetable crop grown for its petioles, seeds and roots/hypocotyls. The petioles are rich in fiber, Vitamins A, B6, C, K and folate as well as micronutrients. With a Plant Sciences Corporate Affiliates Partnership Program grant, in collaboration with BASF Vegetable Seeds and Bejo B.V., the SBC is assembling and annotating the celery genome. It will lay the foundation for genomics-assisted breeding in this important California crop. This work is in collaboration with Lynn Epstein (UC Davis) and conducted by Armando Garcia-Llanos and Shiyu Chen.

Chicory and Endive: Annotating the genomes to assist in breeding

Leafy greens are increasing in value and demand as people are asking for a more diverse diet. Chicory and endive are important greens also used for their roots. In collaboration with Richard Michelmore (UC Davis) and Rijk Zwaan B.V., the SBC is assembling and annotating the genomes of these species to enable genome assisted breeding of these crops. The work uses the latest technologies such as Oxford Nanopore, Hi-C and 10X Genomics. Armando Garcia-Llanos and Shiyu Chen are developing the resource.

Cotton: Improvement of transformation efficiency in cotton

The advent of gene editing technologies such as CRISPR/Cas9 can dramatically increase our ability to tailor phenotypes and determine gene functions for crop improvement. This requires an efficient regeneration system that is currently limiting progress in cotton. In an effort to enable functional genomics and gene editing in cotton, the SBC is collaborating with David Stelly (Texas A&M University) to develop novel transformation systems in cotton. We are optimizing pollen-transformation using carbon nanotubes with Markita Landry (UC Berkeley). Research indicates that specific stages of pollen development may be essential for success. Ph.D. student Sirisupa (Trent) Sripolcharoen is conducting this research and the project was supported by Cotton Incorporated.

Melon: Rapid phenotyping for quality

Allen Van Deynze, Kent Bradford and Dario Cantu (UC Davis) are collaborating with HM.Clause to develop high-throughput methods for phenotyping melon quality. Postdoctoral researcher Macarena Farcuh has compared the results from sensory analyses for texture on field-grown melons with those from various instruments that can be efficiently deployed in the field for rapid phenotyping of breeding populations. Results from 2 years show a strong correlation between sensory analysis and texture measured with the Texture Analyzer. In 2019, research was extended to studying aroma and taste, which included training of sensory panels to accurately identify subtle differences in melon quality at different maturity stages. This research is funded by HM.Clause.
Pepper: International collaboration on resistance to nematodes and late blight

The SBC is working with Jose Luna-Ruiz (Universidad Autonoma de Aguascalientes, Mexico) to study the inheritance and develop genetic markers for resistance genes to nematodes and late blight in pepper. Field and greenhouse phenotyping has been carried out by a master’s student in Mexico who has been trained in sequence-based genotyping and analyses at the SBC. Visiting scientist Heshan Du, from Beijing Vegetable Research Center, conducted the genotyping for the project. The project is funded by UC Mexus.

Designing a pepper for mechanical harvesting

Mechanical harvesting of pepper is a goal for the industry due to increasing costs and reduced availability of labor. As in tomato, both harvesters and breeding varieties amenable to mechanical harvesting are required. Although this has been achieved largely in ripe paprika types, it is still a challenge to harvest green jalapeno, other chiles, and bell types by machine. Several traits are essential: to be able to destem the fruit from the pedicle, to ensure uniform ripening and to adapt plant architecture to mechanical harvesting. The SBC identified a unique accession from wild accessions in Mexico that destems well and has good pericarp thickness. The trait has been transferred to jalapeno/serrano types and verified in field trials in New Mexico using an Etgar Inc. harvester. The results show that the force to destem is directly correlated with amenability to mechanical harvesting. In 2019, several breeding populations combining traits for jalapeno and New Mexico types were evaluated and advanced. Genetic mapping of the trait indicates a unique pathway is involved in controlling destemming. Theresa Hill and Shiyu Chen in collaboration with Stephanie Walker, New Mexico State University, worked on this program with support from USDA/NIFA and a UC Davis Science Translation and Innovative Research grant.

Spinach: Breeding baby leaf spinach for resistance to downy mildew and quality

Allen Van Deynze is co-leading a breeding program with Charlie Brummer (director, UC Davis Plant Breeding Center) focusing on developing broad genetic resistance to downy mildew in baby leaf spinach. Juliana Osorio-Marin is the plant breeder implementing the program in collaboration with Steve Klostermann, Amy Achieta and Shyam Kandel (USDA/ARS) from Salinas. Allison-Krill Brown joined the team in 2019. The program developed and screened 725 families from 31 populations in conventional and organic fields in the Salinas Valley for disease resistance, low uptake of cadmium and leaf quality in 2019. Selections are intermated and advanced. Biparental and multi-parental populations have been developed for testing and genetic mapping of traits. We have developed rapid assays to detect downy mildew in the field and are sequencing races of downy mildew to better understand spinach-pathogen interactions. Samantha Hilborn (Masters student) and Mychele Batista Da Silva and Arsenio Ndeve (both postdoctoral scientists) support the program. This program is funded by the California Leafy Greens Board and the California Spinach Committee, with additional support from USDA/ARS and a Specialty Crops Research Initiative block grant to extend breeding for organic systems.

Breeding spinach for nitrogen use efficiency (NUE)

The SBC is working with Vijay Joshi (Texas A&M) to develop baby spinach varieties with high nitrogen-use efficiency (NUE). Currently, growers use 100-200 kg/ha of nitrogen to grow baby spinach to meet consumer and grower demands for rapid growth and a dark green product on this 3-4 week crop. It has been shown that most crops only use 50% of nitrogen applied, resulting in leaching into water systems. Oon-ha Shin (PhD student) is working with Allen Van Deynze, Charlie Brummer and Juliana Osorio-Marin to screen 350 lines of spinach in the field for NUE. Initial data indicate a large variation for this trait in baby spinach. Over 1500 gene-based markers are being screened in this germplasm to establish a genomics-assisted breeding program for NUE. This work is funded through the USDA Specialty Crops Research Initiative.
RESEARCH AND PUBLICATIONS

SBC Research Team


Scientific Publications by SBC Researchers in 2019


SBC Advisory Council

- Phil Ashcraft, Stason Farms
- Charlie Brummer, UC Davis Plant Breeding Center
- Rich Collins, The Collins Farm
- Jovan Djordjevic, BASF
- Rick Falconer (Chairperson), Rijk Zwaan
- Dan Gardner, S&W Seed Co.
- Gilles Gay/Cecilia Chi-Ham, HM.Claude
- George Gough, Bayer Crop Science
- Gary Hudson, Hudson & Associates, Inc.
- Matthew Johnston, Syngenta
- Francois Korn, SeedQuest
- John Palmer, California Crop Improvement Assn.
- John Purcell, Bayer Crop Science
- Howard-Yana Shapiro, Mars Incorporated
- Gail Taylor, UC Davis Department of Plant Sciences
- Bill White, White Seed Company
- Chris Zanobini, California Seed Association
- Jeff Zischke, Sakata Seed America
SBC Celebrates 20 Years

The SBC proudly celebrated our 20th Year Anniversary on September 12th. The celebration included a day-long symposium focusing on the future of SBCs three pillars, Research, Education and Outreach. Panelists Richard Michelmore and Christine Diepenbrock (UC Davis), Cecilia Chi-Ham (Inari), and Jeff Zischke (Sakata Seeds) highlighted Crop Breeding. Derek Bewley (University of Guelph), Alfred Huo (University of Florida), Johan Van Asbrouck (Rhino Research, Thailand), and Keith Kubik (HM.Clause) discussed Seed Production and Quality. Gail Taylor, (UC Davis), Claudia Germeshausen (HM.Clause), Laura Brown (Enza Zaden) and Rita Mumm (director, African PBA) discussed Education and Katie Murphy, (moderator, UC Davis), Alison van Eenennaam (UC Davis), Andy Lavigne (American Seed Trade Association), Matthew Johnston (Syngenta), Peggy Lemaux (UC Berkeley) and Sekhar Boddupali (Intrexon) underscored Outreach. In addition, we recognized and celebrated two of the pioneers who helped bring the SBC to fruition, Kent Bradford and Sue DiTomaso.

Kent Bradford and Sue DiTomaso Retire

After 20 years of service to the SBC, director Kent Bradford and associate director Sue DiTomaso retired in July. Kent and Sue were two of the pioneers who helped to create the SBC in 1999. Perfectly complementary in their contributions, Kent has served as our steadfast faculty leader while Sue managed overall center operations and administration, including program and outreach development and financial and personnel management (sustaining a happy staff). Kent and Sue will be greatly missed!

Our best wishes to them in their retirement.

Seed Biotechnology Center, UC Davis
Seed Biotechnology Center

14 Crops researched
$19,001,858 in Research grant funds
20 SBC years

12,008 Students trained
70 Countries
349 Companies

20 Workshops
64 Programs held/hosted
98 Seed Central Forums
64 Programs
3111 Seed Central attendees

145 Publications
16 Staff members

OUR TEAM

ALLEN VAN DEYNZE
JOY PATTERSON
PHYLLIS HIMMEL
JULIE TILLMAN
REBECA MADRIGAL
KELSEY MAHER
SUSAN DITOMASO
RALE GJURIC
KENT BRADFORD
The Past is Prologue

As is highlighted in this 2019 Annual Report, we celebrated the 20th anniversary of the founding of the Seed Biotechnology Center (SBC) in September. In last year’s Annual Report, I recounted some of the events and acknowledged some of the people surrounding the creation of the SBC and highlighted those who have been instrumental in its accomplishments since then. Both Susan DiTomaso and I retired in June 2019, and the SBC has been in the process of transitioning to new leadership. We are fortunate that Allen Van Deynze agreed to become the Director of the SBC, and our excellent staff have distributed the countless tasks that Sue previously handled. Thus, we can rest assured that the SBC is in good hands and will continue to provide research, education and outreach to serve the needs of its stakeholders.

In this farewell essay, I want to address some themes that I mentioned in my presentation at our 20th Anniversary Symposium, which I called “The Past is Prologue.” Shakespeare’s phrase means that “history sets the context for the present,” which is appropriate for our anniversary, but it is also relevant to the seed industry, as in the American Seed Trade Association’s motto, “first the seed”. The knowledge, technology and care invested in the seed is prologue to crops that have improved yields, quality and nutrition. Based on past achievements, what stories might be in the 30th anniversary issue of this report? In many cases, this will depend not only on the efforts of scientists and researchers, but also on policy decisions and public opinions affecting how or whether we able to implement new knowledge and innovations.

Genetic Improvement Methods. The trajectory in crop breeding and improvement for the next decade depends strongly on the global society’s response to modern breeding methods, particularly gene editing and genetic engineering. Currently, countries around the world are dividing into two camps, one enabling some limited use of these methods, and the other effectively banning them. In the first camp, we can celebrate that the regulatory systems in the U.S. and some other countries will now allow certain uses of gene editing without prohibitive testing or prescriptive labeling. However, the uses are limited to what could be achieved (though much more slowly) using conventional breeding. This is like telling an engineer in a warehouse full of computer chips and parts that she is free to innovate and create, just so long as she doesn’t mix up any parts from different shelves or make anything truly novel, like a smartphone. Biologists have a warehouse of genes developed and tested by 3 billion years of evolution available, but can’t borrow parts from another organism, even though we know that this is common throughout biology and we have 25 years of experience with the prototypes in the field without any safety issues. As I write this in isolation from Covid-19, I am so grateful that medical scientists are able to use the full complement of modern biotechnologies to create an effective vaccine as quickly as possible.

However, once we have that vaccine and the threat from the virus has passed, the world will still need to increase food production by 70% before 2050 while protecting food products from pests and decay. Our breeders, agricultural scientists and farmers are being asked to meet that challenge, but to use only methods and components that were available to their great-grandfathers. And if they nonetheless are able to make advances using these newer tools, be assured that the Non-GMO Project and its allies will be poised to scare marketers and consumers away. For those countries in the second camp, who refuse to allow any modern biotechnologies in agriculture, good luck trying to meet your food production needs sustainably in a rapidly changing environment. And, by the way, it’s not fair to hamstring your own farmers and just export your demand (and carbon footprint) to other countries struggling to meet their own needs.
In an alternative scenario for the future, the hands of scientists are untied and they are able to use the full catalog of available biological and technological tools. Imagine what could be achieved in that case, if we were able to pursue strategies and products that we already know will work and bring them to market immediately for appreciative farmers and consumers. Here are just a few scenarios in seed science.

**Seed Biology and Production.** There are clear avenues to enable us to control flowering and reduce dependence of seed production on environmental signals such as temperature and day length, which would be very useful in dealing with climate change. We could have “flowering on demand,” enabling rapid advancement of generations and uniform flowering for higher seed quality and nicking of hybrid parents. In fact, development of apomixis (clonal propagation through seeds) would revolutionize production of hybrid seeds. We could control the generation in which specific traits are expressed, for example, having high quality maize seeds that in the next generation automatically turn off one gene to make sugary sweet corn. We could have seeds with higher nutritional content (no consumers have yet eaten Golden Rice, despite half a million children blinded or deceased annually due to vitamin A deficiency since 2005 just because it required some parts from another shelf in the biological warehouse). We could immunize plants against their worst pathogens and insect pests, obviating the need for pesticides.

**Seed Technology.** Digital imaging, robotics and artificial intelligence will be routinely applied to analyze, sort, upgrade, plant and/or transplant crops. Seeds characterized physically and chemically via multispectral cameras and other sensors and sorted on these features will upgrade homogeneity and performance. Similar applications to grains and pulses during food processing will enhance product quality and safety. Seed testing will be performed by standardized robotic analysis systems assisted by both digital imaging and physiologically based quality parameters such as respiration rates. Seed treatments will include microbes selected or modified to provide nutrients, prevent disease and promote growth. Getting those microbial enhancements to work in practice will require new generations of seed priming technology that will also improve seed performance.

**Seed Storage.** Storage of seeds is essential, whether it is for planting the next season or for conserving germplasm forever. In the case of grains and pulses, seeds also are the commodity products that must be protected from spoilage and pests and the toxins associated with them. In some climates with relatively low humidity and moderate temperatures, including California, this is not hard to do. In the tropics, however, seeds die quickly in the constant high humidity and temperature, and fungi growing on stored commodities produce mycotoxins such as aflatoxin. We know how to prevent this by implementing the Dry Chain, which is simply to make them dry (including the use of desiccants in humid climates where heated air is less effective) and keep them dry (by hermetic packaging). As global temperatures increase, implementing the Dry Chain will be critical for preserving planting seeds and preventing the food and nutritional losses of up to 30% that occur between the farmer and the consumer in many tropical countries.

These alternative futures are open to us, dependent upon the choices and policies that we make now. If we had unlimited time, it might be prudent to go slow and sacrifice some potential benefits to the precautionary principle. But we have only 30 years to feed an additional 2 billion people, reduce our net carbon generation to zero, and adapt to the climatic changes that are already underway. In the current Covid-19 crisis, governments and the public are rediscovering the value of science and facts. I hope that this change in values and urgency extends to crop and seed improvement as well.

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MISSION

The mission of the Seed Biotechnology Center is to mobilize the research, educational and outreach resources of UC Davis in partnership with the seed and biotechnology industries to facilitate discovery and commercialization of new seed technologies for agricultural and consumer benefit.