Seed Biotechnology Center
at UC Davis

ANNUAL REPORT
2015
Public-private Collaborations Are Not Conspiracies

The land-grant university system and its associated Cooperative Extension programs represent a unique strength of U.S. agriculture. Created by Abraham Lincoln and Congress during the Civil War, the public universities in this nationwide Agricultural Experiment Station (AES) system conduct research to discover new innovations and provide education to students, farmers and the agricultural industry. This system has been highly successful in enhancing agricultural productivity and sustainability as well as keeping food costs lower for consumers. The AES is designed to encourage interactions between academic researchers and all aspects of the agricultural industry, effectively directing research toward real problems and disseminating improved practices and technologies to end users.¹

This 154-year history of successful partnership and cooperation is threatened by detractors who assume that any contact between academics and commercial entities must contain a conspiracy in which the researchers are being paid to subvert the truth. One such organization, called U.S. Right to Know (USRTK.org), has filed state Freedom of Information Act (FOIA) requests for at least 43 public university faculty and staff across the country who they claim are used by companies “as sock-puppets to shape the media narrative on food issues, particularly GMOs.” In February 2015, USRTK requested communications that I (and additional colleagues at UC Davis) had with a long list of companies and organizations over a three-year period (2012-2015). We are complying fully with the provisions of the California Public Records Act and UC Davis legal staff are reviewing all of our relevant email communications during that period to determine those that are subject to the request. We will utilize valid and legal exemptions to prevent release of some of these messages related to research programs, but many of the companies and organizations that have long been partners with the Seed Biotechnology Center (SBC) may find that some of their private communications with me will be released.

Similar FOIA requests have been criticized as harassment and as threatening the scientific process. Scientists working on climate change in particular have been subject to virulent attacks via open records laws. As the Center for Science and Democracy of the Union of Concerned Scientists reported, “individuals and well-heeled special interests across the political spectrum are increasingly using broad open records requests to attack and harass scientists and other researchers and shut down conversation at public universities. … This strategy can curb the ability of researchers to pursue their work, chill their speech, and discourage them from tackling contentious topics.”²

With respect to the SBC, it is instructive to review its original and current mission statement:

“To mobilize the research, educational and outreach resources of the University of California, in partnership with the seed and plant biotechnology industries, to facilitate discovery and commercialization of new germplasm and seed technologies for agricultural and consumer benefit.”

This statement is completely transparent about who we are, who our partners are, and what our goals are. We have published reports annually for 15 years in which we describe our research, education and outreach activities and give full credit to the companies, foundations, and government agencies that provide funding for those programs.³ We have posted summaries of our sources of revenue on our website and have provided our best scientific judgement to anyone who asks. As you know by working with us, our opinions on policy issues are based on facts and science, not on funding sources. We are not a “sock-puppet” or “shill” for anyone. We strongly reject USRTK’s fundamental premise that public-private collaborations are conspiracies and that public researchers modify or bias data or opinions to suit the objectives of their funders. Consider that concept for just a moment: is it really believable that groups sponsoring research at the top agricultural university in the world expect to

¹http://uacnr.edu/sites/californiaagriculture/files/160969.pdf
²Freedom to Bully, www.ucsusa.org/openrecordsabuse
³http://sbc.ucdavis.edu/News/Reports_and_Brochures_655
receive false or misleading information? Would you want to base the future success of your company or organization on false or biased research, and pay for the privilege of getting it? This is inherently absurd.

These broad FOIA requests are an attack on science and on the trust that the public properly has in its academic institutions. I regret the need to share this threat to our research, education and public service activities with stakeholders and partners of the Seed Biotechnology Center. I also regret that our interactions could result in exposing some of your own communications to public release. I am not concerned about the content of our communications, although I cannot prevent selective editing or release by USRTK in their attempts to justify their false conspiracy theories. On behalf of the SBC, I guarantee that we will strongly resist efforts to stop our work and will continue to uphold the highest scientific and ethical standards in all of our activities—you would expect nothing less.

I hope that you will enjoy reading about our activities during 2015 that highlight the benefits of partnerships, including the “uncommon collaboration” of the African Orphan Crops Consortium (see page 8) and the Innovation Institute for Food and Health co-sponsored by UC Davis and Mars, Incorporated (see page 30 for Howard Shapiro’s commentary). We really can do more by merging the strengths of both public and private research and development communities.

Director, Seed Biotechnology Center
University of California, Davis

Consider this concept for just a moment: is it really believable that groups sponsoring research at the top agricultural university in the world expect to receive false or misleading information? Would you want to base the future success of your company or organization on false or biased research, and pay for the privilege of getting it?

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EDUCATION

Plant Breeding Academy℠

The University of California, Davis (UC Davis) Plant Breeding Academy (PBA) has been offered since 2006 with classes in the USA, Europe, Africa and Asia. To date, the program has trained more than 200 breeders, 80% of which are from the private seed industry. 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 (UC Davis), Rita Mumm (University of Illinois), Todd Wehner (North Carolina State University), Idy van Leeuwen and Alexandra Tomerius. They are supported by a number of guest lecturers from the private industry and academia.

PBA Highlights in 2015

European Plant Breeding Academy Class III graduated in June

The UC Davis European Plant Breeding Academy (EPBA) graduated its third class with a session in Davis, California. Over the last two years, during the six sessions held in Gent, Belgium; Angers, France; Gatersleben, Germany; Enkhuizen, The Netherlands; Almeria, Spain, and UC Davis, nineteen participants in this class spent more than 300 hours in classes, workshops and the field, training towards the Plant Breeding Academy Certificate.

The recipient of the European Seed Association (ESA) “Outstanding Student Award” for the third class of the EPBA was Volker Marwede, from Norddeutsche Pflanzenzucht Hans-Georg Lembke KG, Germany. Over the course of the program, Dr. Marwede showed superior performance in terms of assignments and the final project. In addition, Dr. Marwede had outstanding support from his peers for his in-class contribution to the learning process. The award presentation took place during the General Assembly at the ESA Annual Meeting in Vienna in October 2015.

Europe Class III course participants include:

- Amine Abbadi, NPZ, Germany
- Justus Boehm, Kartoffelzucht Boehm, Germany
- Estelle Bonieu, DuPont Pioneer, France
- Jordi Caujape, Semillas Fitó S.A., Spain
- Jagdeep Singh Cheema, Doctor Seeds, India
- Jan de Groot, Dialsoft Beheer B.V., Netherlands
- Miklos Fazekas, Alfaseed, Hungary
- Ersel Göroglu, Semillas Fitó, Turkey
- Hanna Haikka, Boreal Plant Breeding Ltd., Finland
- Jure Kolaric, Saatzucht Gleisdorf GmbH, Austria

ANNUAL REPORT 2015
European PBA starts fourth class

To assist in meeting growing demand for trained plant breeders, the UC Davis European Plant Breeding Academy (EPBA) started its fourth class of students in October with its first session in Enkhuizen, The Netherlands. Over the next two years, during the remaining five sessions to be held in Angers, France; Gatersleben, Germany; Gent, Belgium; 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 certification program. For more information on the Plant Breeding Academy, please contact Volker Marwede at vmart@ucdavis.edu or visit PBA.ucdavis.edu.

Europe Class IV course participants include:
- Remy Adriaensen, Bayer CropScience, Belgium
- Antonio Alamo, Fall Creek Farm, Spain
- Sienna Bacaiz, Syngenta, Spain
- Solene Crepelle, Syngenta, France
- Grégory Lavric, KWS Momont, France
- Alessandra Lillo, Driscoll’s Genetics, UK
- Przemyslaw Matysik, Hodowla Roslin Strzelce, Poland
- Nina Muellers, KWS SAAT SE, Germany
- Bear Reel, CW Botanicals, USA
- Michal Rokicki, Poznanska Hodowla Roslin, Poland
- Adam Siemtarski, Driscoll’s Genetics, Poland
- Erik Van der Biezen, Bayer CropScience, Belgium
- Arie Vana, Israel

Davis Class V completed three 2015 sessions, in February, June, and September.

Davis Class V course participants include:
- Marta Baptista, Driscoll’s Strawberry Associates, USA
- Ray Cowley, DuPont Pioneer, Australia
- Ryan Eady, Halls Plant Farm, USA
- Pieter (PJ) Fourie, Hygrotech, South Africa
- Ezequiel Gallegos, Nunhems, Mexico
- Evan Gillis, DL Seeds, Canada
- Lluvia Gutierrez, Driscoll’s Strawberry Associates, USA
- Marilyn Hino, East-West Seed Co., Phillipines
- Sean Keyworth, HM.Clause, USA
- Jace Knight, Dixon Seed, Inc., USA
- John Larse, Larse Farms, Inc., USA
- Jeff Mansiere, Bayer CropScience, Canada
- Curtis Van Laecke, Horizon Seeds Canada, Inc., Canada
- Eric Willard, RJ Reynolds Tobacco Co., USA
- Josh Williamson, Nuhems/Bayer, USA

Erkan Konuk, May Agro Seed, Turkey
Anders Soendergaard Larsen, DLF-Trifolium, Denmark
Bert Lataire, Bayer CropScience NV, Belgium
Volker Marwede, NPZ, Germany
Malgorzata Niewinska, Danko Hodowla Roslin Sp. z o.o., Poland
Alexis Oger, Syngenta, France
Franziska Roth, Bayer CropScience, Germany
Simone Sendke, Monsanto, Germany
Alexander Strube, Saaten-Union Recherche S.A.S., France
African PBA starts second class

After a successful graduation of 21 of Africa’s top plant breeders in December 2014 from the inaugural class of the African Plant Breeding Academy (AIPBA), the SBC recruited its second class for the program under the direction of Rita Mumm, director and lead instructor. The first class formed a cohort of professionals equipped with the latest tools (see AOC) who are currently collaborating in new projects and grants received in crops important to African diets such as beans, lentil, sweet potato, spider plant, yams, finger millet, fonio, teff, and shea tree. After sorting through 252 applications, 29 mid-career plant breeders from 27 institutions with active plant breeding programs in Africa were invited to join the program with full scholarships provided by Mars, Incorporated. The class represented professionals from 16 countries across Africa including 7 women. Class II opened at the International Institute for Tropical Agriculture in Dar es Salaam, Tanzania on November 30. These professionals will attend 3 two-week sessions over 13 months. Instructors for the Academy include experts from academia and industry professionals including Rita Mumm, Iago Hale, Bruce Walsh, Todd Wehner, Allen Van Deynze, Kent Bradford and Rale Gjuric. Local support for the AIPBA is provided by The World Agroforestry Centre (ICRAF) director Tony Simons with logistical support from Imelda Ingumba and Mehmood Hassan. Logistical support at the SBC is provided by Sue DiTomaso and Sally Mohr. Over five years, the academy aims to train 120 of the top African plant breeders the latest strategies in plant breeding including population improvement, quantitative genetics, selection theory, objective phenotyping and application of genomics to plant breeding. The goal is 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.

Africa Class II course participants include:
Abe Gerrano, Agricultural Research Council-Vegetable and Ornamental Plant Institute, South Africa
Abush Tesfaye Abebe, Ethiopian Institute of Agricultural Research, Ethiopia
Charity Chidzanga, Scientific and Industrial Research and Development Center (SIRDC), Zimbabwe
Charles Amadi, National Root Crops Research Institute, Umudike, Nigeria
Charles Mutimaamba, Crop Breeding Institute / Dept. of Research & Specialist Services, Zimbabwe
Daniel Nyadanu, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Dowliya Benjamin Nzawe, Institut National pour l’Etude et la Recherche Agronomiques (INERA), DR Congo
Emmanuel Chamba, CSIR-Savanna Agricultural Research Institute, Ghana
Enoch Gbénéto Achigan Dako, Horticulture and Genetics Unit/ Faculty of Agromonic Sciences/University of Abomey-Calavi, Benin
Fulgence Niyongabo, Institut des Sciences Agronomiques du Burundi (ISABU), Burundi
Gemechu Keneni, Ethiopian Institute of Agricultural Research, Ethiopia
Gladys Amoding, NARO/National Semi-Arid Resources Research Institute, Uganda
Happiness Oselebe, Ebonyi State University, Abakaliki, Nigeria
Innocent Habarurema, Rwanda Agriculture Board (RAB), Rwanda
Josephine Therese Makueti, World Agroforestry Centre West & Central Africa, Cameroon
PBA Advanced Module

Twenty-seven breeders/researchers representing public and private organizations from the USA (UC Davis), Canada, France, Germany and Argentina, participated in the first open offering of the Advanced Module Plant Breeding Academy, held in Davis, CA, November 3-5, 2015. Among the participants was the second recipient of the "Larry Teuber Memorial Scholarship," UC Davis PhD student Jareerat Chunthawodtiporn. The module is designed to review the breeding strategies in context of the modern tools, build the necessary background towards understanding and practical application of BLUPs, genomic selection, advanced experimental designs and dealing with testing environments. UC Davis instructors, Allen Van Deynze and Rale Gjuric, were joined by Bruce Walsh, University of Arizona, to deliver this program.
African Orphan Crops Consortium

The African Orphan Crops Consortium’s (AOCC) objectives are to improve the nutrition, productivity and climatic adaptability of some of Africa’s most important indigenous food crops to decrease the malnutrition and stunting that is rife among the continent’s rural children. The AOCC (see www.africanoorphancrops.org for annual report) has begun by investing in training Africa’s top breeders to integrate modern tools into their plant breeding programs. The next objective is to sequence the reference genomes and 100 genotypes for each of the 101 African orphan crops selected by the program. In addition, 2015 began with receipt of the Greater Good Initiative Award from new partner, Illumina, Inc. The AOCC also added UNICEF, the African Research Council and FAO (the Food and Agriculture Organization of the United Nations) to the Consortium.

In 2015, through BGI and the AOCC lab at the World Agroforestry Centre, whole genome sequencing is at assembly stage for the genomes (African names in parentheses) of Acacia, African eggplant (Ngogwe), Bambara groundnut (Ngugu), bread fruit (Mshelisheli), custard apple (Mtokwe), finger millet (Wimbi), fonio, lablab bean (Mfiwi), and Moringa (Mzunzie). Ten more genomes are in process of whole genome sequencing. The AOCC lab has also been sequencing up to 100 lines in finger millet, bean and spider plant with samples from an additional 16 species in preparation. RNA is being prepared from 19 species for transcriptome sequencing at the Agricultural Research Council, University of Pretoria. All data created by the AOCC will be publicly available.
Significant contributions by AOCC partners

- **Alliance for a Green Revolution in Africa, AGRA (Nairobi, Kenya)** Support for the Plant Breeding Academy
- **BeCA/ILRI (Nairobi, Kenya)** Lab and project support and training of breeders. Curation of germplasm used by AOCC
- **BGI (Shenzhen, China)** Sequence, annotate, assemble and curate 101 African orphan crop genomes
- **Google (Mountain View, USA)** Provide rapid transfer of data worldwide using cloud space
- **Thermo Fisher (Waltham, USA)** Four Proton sequencers and 4 Chef Stations and reagents for 10,000 African orphan crop lines
- **LGC (Hoddesdon, United Kingdom)** Genotyping services for AOCC plant breeders
- **Mars, Incorporated (Maclean, USA)** Support for the African Plant Breeding Academy, scholarships for breeding programs and support for AOCC lab personnel
- **NEPAD (Nairobi, Kenya)** Administration and development for the AOCC
- **Illumina Inc. (San Diego, USA)** Provide reagents to sequence the gene complement of 50 species
- **iPlant Collaborative (Tucson, USA)** Analysis and curation of sequence and genotype data
- **UC Davis (Davis, USA)** Delivering the African Plant Breeding Academy and lab support
- **UNICEF (New York, USA)** Provide support for development of AOCC
- **VIB-PSB/University of Ghent (Ghent, Belgium)** Bioinformatics and annotation of plant genomes
- **World AgroForestry Centre (Nairobi, Kenya)** Hosting the AHPBA, construction and management of AOCC lab and data
- **World Wildlife Federation (Washington, DC)** Project initiation and vision

The AOCC network continues to increase including:

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<th>Agricultural Research Council</th>
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<td>Crops for the Future Research Centre</td>
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<td>Subtropical Horticultural Research Station, USDA-ARS</td>
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<td>Finger Millet Consortium</td>
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<td>Hohenheim University</td>
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Other SBC Educational Courses

Seed Business 101

This one-week program is designed to expose participants to the five functional areas of a seed company: research and development, production, operations, sales and marketing and administration. The course content is delivered in a very interactive way by creating a virtual seed company and case studies for each functional area. The program provides those new to the seed industry a broad understanding of the major aspects of a seed company’s operations and cross-departmental knowledge of best practices for profitability. The class is taught by widely respected industry executives with additional help of experts participating as guest speakers. Starting in 2012 we began offering two distinct programs, one focusing on field crops and the other on horticultural crops. More than 350 participants have completed this course since 2010.

The following sessions were offered in 2015:
- Horticulture — March, Davis, California, USA
- Field Crops — December, Chicago, Illinois, USA
- Horticulture — December, Davis, California, USA

Instructor Kent Bradford (far left) assists Seed Biology, Production and Quality course participants at the microscope.

Thank you HM.Clause for your terrific support!
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Thank you HM.Clause for your terrific support!

Seed Biology, Production and Quality

This unique two and a half day course is designed for professionals in the seed industry, crop consultants and growers to update and expand their current knowledge. It is critical that seed producers have an understanding of the biological factors that contribute to the development and maintenance of seed health, vigor and viability, and how those qualities are measured. This course presents the scientific background for production, handling, storage and quality control procedures in the seed industry. It updates participants on new information in these topics, including seed pathology and seed enhancement. The course targets professionals in the seed industry, new employees, consultants, and seed producers to extend and update their knowledge. The 58 participants came from countries around the world including Canada, Italy, Japan and various states in the US. The 2015 instructors included Pedro Bello, Robert Gilbertson, Kent Bradford (all UC Davis), Derek Bewley (University of Guelph, Canada), Lindsey du Toit (Washington State University), Henk Hilhorst (Wageningen University, The Netherlands), Peter Marks (Aginnovaton, LLC), Deborah Meyer (California State Seed Laboratory), Ronald Michaels (Phenotype Screening Corporation), Hiro Nonogaki (Oregon State University, Corvallis) and Mike Pereira (Granum Services, LLC).

OUTREACH AND PUBLIC SERVICE

Plant Breeding for Food Security: The Global Impact of Plant Genetics in Rice Production

In May, the Plant Breeding Center (PBC), in collaboration with the Confucius Institute, hosted the Plant Breeding for Food Security symposium. The symposium focused on the global impact of plant genetics on rice production in honor of the work of UC Davis Alumnus and Adjunct Professor, Dr. Gurdev Khush. Over 200 guests came from all over the world to attend the day-long symposium to discuss the advances of global production in rice, wheat, and tomato, the future obstacles that face an ever-growing world population, and the technologies to address them. The SBC was pleased to be involved with the event and to help establish the Gurdev Khush Conference Room, located in the Plant Reproductive Biology building that hosts the SBC and the PBC.
Seed Central

Seed Central/Food Central

Seed Central/Food Central (SC), an initiative of the Seed Biotechnology Center and SeedQuest, began in 2010. Since then, over 1,200 people from some 200 companies and organizations from California, the U.S. and overseas have attended the Seed Central events. The purpose of SC is to energize the seed industry cluster surrounding UC Davis and to bring science to market faster. Seed Central activities are funded via industry memberships and sponsorships. It is a non-profit corporation and the SBC serves as its UC Davis liaison. To attend the Forums and value-added afternoons, please mark your calendar on the second Thursday of each month (during the academic year) and join us. Each Forum typically has more than 100 students, faculty, industry and economic development people in attendance, providing a truly unique and powerful networking opportunity. More recently there are two programs dedicated to our Salinas neighbors. Back at UC Davis, in addition to Forums, three value-added afternoons each year feature lively brainstorming and science sessions. Visit www.SeedCentral.org for a complete list of activities.

2015 Seed Central/Food Central Forum Presenters and Topics

- **Bruce German**, Professor & Director, Foods for Health Institute, Department of Food Science & Technology, UC Davis | *Catalyzing Innovation in Food and Health at UC Davis: Challenges and Solutions*
- **Alex Cochran**, Global Director Research and Development, DuPont Seed Treatment Enterprise | *Emerging Seed Treatment Technology: Introduction of the Anthranilic diamides*
- **Inmaculada Ferriol Safont**, MS, Prof. Bryce Falk’s Group, Plant Pathology Department, UC Davis | *Torradoviruses*
- **Tera Pitman**, MS, Prof. Bryce Falk’s Group, Plant Pathology Department, UC Davis | *Cucumber Green Mottle Mosaic Virus*
- **Deborah Golino**, Director Foundation Plant Services, Plant Pathology Department, UC Davis | *Specialty Crop Clean Plant Centers: Managing Plant Health Through Pathogen Screening and Distribution of Plant Materials*
- **Dario Cantu**, Assistant Professor, Department of Viticulture and Enology, UC Davis | *Integrative Genomics Approaches to Improve Grapevine Disease Resistance*
- **Neal Gutterson**, Vice President of Agricultural Biotechnology, DuPont Pioneer | *DuPont Pioneer Ag Biotech R&D: Strategy and Future Directions*
- **Joseph DiTomaso**, CE Weed Specialist, Department of Plant Sciences, UC Davis | *The Interaction of Seed Biology in Weed and Invasive Plant Management*
- **Charles Brummer**, Director, Plant Breeding Center, UC Davis | *Plant Breeding for the Future*
- **Kent S. McKenzie**, Director, Rice Experiment Station, California Cooperative Rice Research Foundation
- **Heather Koshinsky**, CSO at Eureka Genomics
- **Allen Van Deynze**, Research Director, Seed Biotechnology Center and Assistant Director, Plant Breeding Center, UC Davis
- **Ryan Hayes**, Research Geneticist, USDA/ARS | *USDA Lettuce Breeding and Genetics*
- **Jose Kawashima**, CEO of MiCafeto Coffee Company | *What Makes the Quality of Coffee?*
- **David Clifford**, Lead Quantitative Researcher, The Climate Corporation | *Joining the Dots from Data Science to Agronomic Insight*
- **Carl Winter**, CE Food Toxicologist, Food Science and Technology, UC Davis | *Mythbusters: Pesticide Residue Edition*
- **Ian Korf**, Associate Professor, Molecular & Cellular Biology, UC Davis | *From Bench to Keyboard and Back: Integrating Experimental Molecular Biology and Bioinformatics to Understand Intron-mediated Enhancement*
- **James M. Weatherly**, Executive Director, Seed Innovation and Protection Alliance, Patent Attorney with Cochran Freund & Young LLC
- **Katherine F. McLaughlin**, Special Agent, Federal Bureau of Investigation | *Economic Espionage*
• **Alissa M. Eagle**, Assistant General Counsel, IP, Monsanto Company, Seminis Vegetable Seeds, Inc. | Application of IP Protection Systems at a Seed Company: What Companies Do/Best Practices
• **John Schoenecker**, Director of Intellectual Property – AMPA, HM.Clause | Introduction to IP at Seed Companies
• **Morven McClean**, Executive Director, International Life Sciences Institute Research Foundation
• **Bernice Slutsky**, Vice President for Domestic & International Policy, American Seed Trade Association
• **Etienne Rabe**, VP of Agronomy, Wonderful Citrus | The California Citrus Industry: Meeting the Challenges to Stay Competitive

**Collaborative Research (CoRe) Laboratory**

Based on feedback from Seed Central members, we have been exploring the concept of building a research facility on campus that would provide laboratory and administrative space for companies, house sponsored research projects, provide access to shared infrastructure, equipment and service programs, and contain space for start-up ventures. The Seed Central team worked with campus’ Design and Construction Management unit to develop plans for such a building that could be located adjacent to the Plant Reproductive Biology building where the SBC is housed. Chancellor Katehi approved the concept pending development of a business plan for extramural funding for construction and operation of the Collaborative Research (CoRe) Laboratory. It is envisioned that companies/tenants would collectively pay for the building construction over a 10-year period and outfit the individual spaces to their own specifications. Interest has recently been expressed by a local development firm that could facilitate progress on the project. If the CoRe Lab could be of value to you, contact the SBC or Seed Central.

**Seed Central Student Programs**

Seed Central offers a number of activities that give students an opportunity to become engaged with the seed industry. They can attend networking events, job shadow industry professionals, compete in our poster competition, participate in our grand-prize internship opportunity and attend monthly field trips. In 2015 we offered our fourth and fifth workshops. **Gary Hudson** (Gary Hudson & Associates) hosted a dynamic session on “Business Success Strategies: The Value of Using Proper Business Etiquette.” Later, **Andres Trillo** (HM.Clause), **Irma Madera** (Monsanto) and **Rick Roggenbuck** (Novozymes, Inc.) taught a very valuable session on “Interviewing Skills.” Two new sessions are planned for 2016.

**Discover Series**

This new series was launched to introduce UC Davis science and scientists to seed, agbiotech and food companies. There is much more basic and applied research than will fit in our established events, therefore this program was introduced. Once a year member companies are invited to UC Davis to meet newly hired faculty. Three times a year, members are invited to hear short presentations by scientists who pursue basic research that has potential to translate into applied research.

**Corporate Affiliates Partnership Program**

The Plant and Seed Sciences Partnership Program (PSSPP) was formally approved in fall 2012. This Corporate Affiliates Partnership Program is an established university model to facilitate research agreements and interactions between stakeholders and the university. The PSSPP offers three “tiers” of
collaboration with a range of benefits. Thanks to the efforts of the Seed Central team and our industry partners, eight “tier two” research consortia have started and one is pending. Together, just over $3 million will be invested into cutting edge research.

- Principal Investigator: Diane Barrett  
  Title: Sensory Description of Cooked Onions  
  Sponsors: Enza Zaden, Bayer CropScience

- Principal Investigator: Anne Britt  
  Title: Tomato Haploid Induction via Transgenic Mutation of CENH  
  Sponsors: Rijk Zwaan, Syngenta Seed

- Principal Investigator: Luca Comai  
  Title: Haploid Induction in Tomato through the CENH3 Effect  
  Sponsors: Rijk Zwaan, Syngenta Seed, Bayer CropScience, Enza Zaden

- Principal Investigator: Luca Comai  
  Title: Efficient, High-throughput Reverse (and Forward) Genetics System for Tomato Using an Optimized TILLING Population  
  Sponsors: Rijk Zwaan, Bayer CropScience, Enza Zaden

- Principal Investigator: Richard Michelmore  
  Title: BGDP (Bremia Genomic Diversity Project)  
  Sponsors: Rijk Zwaan, Enza Zaden

- Principal Investigator: Richard Michelmore  
  Title: ILGC (International Lettuce Genomics Consortium)  

- Principal Investigator: Allen Van Deynze  
  Title: Defining the Genetic Determinants of Fruit Size and Shape in Pepper  
  Sponsors: Rijk Zwaan, Enza Zaden

The Vegetable Research and Development Forum

At the suggestion of its members and in consultation with the American Seed Trade Association, Seed Central organized the Veg R&D Forum, a meeting of the research managers of vegetable seed companies with breeding activities for the North American market. The purpose was to enable discussion amongst research managers of long-term, pre-competitive research topics and research-related policy issues of importance to the North American vegetable seed industry, with invited participation by other relevant specialists such as university scientists, technology providers to the seed industry, and members of the downstream agriculture & food industries. The event was held in April 2014. In 2015 a comprehensive survey was sent to rank the need for research for certain areas. Those findings were tallied and have determined the agenda for the next conference that will be offered in November 2016.

Collaboration for Plant Pathogen Strain Identification (CPPSI)

The mission of the Collaboration for Plant Pathogen Strain Identification (CPPSI) initiative is to build a science-based system for standardizing the identification of plant pathogen strains and races using sets of plant host differentials, reference plant pathogen strains and instructional white papers.

In July 2015, Phyllis Himmel, Ph. D. was hired as the CPPSI Director to lead and grow this initiative. During the first six months, working plans were developed and implemented that focused on outreach to sponsoring seed industry members and critical EU and US partners, technical reviews of existing white papers, continued disease set (differential host sets, reference plant pathogen strains and instructional white papers) development and identifying sources of additional funding.

Meetings with members of sponsoring seed industry members and critical US and EU contacts were held to launch CPPSI as part of the UC Davis Seed Biotechnology Center, explain the mission, build a strong foundation for collaboration and identify steps to promote the consistent naming of plant pathogen strains as future disease sets are developed by CPPSI, NAKT (The Netherlands) and GEVES-MATREF (France). Three articles about CPPSI were written and distributed to the vegetable seed industry. Six presentations were given at professional and trade meetings that described CPPSI priorities, goals and operations. Actions identified during CPPSI meetings with research, regulatory and registration counterparts in Europe were focused on comparative ring testing of existing and developing disease sets to identify equivalent
Collaboration for Plant Pathogen Strain Identification

OUTREACH & PUBLIC SERVICE

Actions identified during CPPSI meetings with research, regulatory and registration counterparts in Europe

Three articles about CPPSI were written and distributed to the vegetable seed industry. Six presentations to launch CPPSI as part of the UC Davis Seed Biotechnology Center

plant pathogen strains and instructional white papers) development and identifying sources of additional partners, technical reviews of existing white papers, continued disease set (differential host sets, reference and implemented that focused on outreach to sponsoring seed industry members and critical EU and US grow this initiative. During the first six months, working plans were developed to initiate the agenda for the next conference that will be offered in November 2016.

Survey results of what the seed industry members would pay for differential host seeds and strains and what MATREF - GEVES actually charges for differential seeds and strains. The pricing plan will be submitted to UC Davis university administration.

Technical reviews and revisions of all four existing white papers (Spinach downy mildew, Melon Fusarium wilt, Pepper bacterial spot and Tomato ToMV) were completed to address the appearance of new pathogen strains and posted to the CPPSI website. The CPPSI website was also updated and domain support transferred to UC Davis. Users from the US, EU, China, Japan, Canada and Finland are accessing information on www.CPPSI.org. Since January 2013, 177 differential host sets were ordered and distributed for research and education purposes, indicating a good level of use by scientists and the general public. In addition, a CPPSI logo was developed.

Development of four new disease sets was proposed by the CPPSI WG and approved by members of the Advisory Council in the fall of 2015. Disease sets of Lettuce downy mildew, Watermelon Fusarium wilt, Pepper TSWV and Tomato TWSV will be developed. Candidates for the third round of differential disease set development will be proposed from the Harmores 3 project and discussed with the CPPSI WG over the summer and with the Advisory Council during the June 2016 ASTA meeting. CPPSI appreciates the continued support from our founding members: Bayer Crop Sciences, Enza Zaden, HM.Clause, Monsanto, Rijk Zwaan, Sakata and Syngenta.

New CPPSI memberships have been discussed with Pioneer DuPont, Eurofins – STA, Bejo and Ag Dia. After some consideration, Pioneer DuPont decided they could not become members at this time. The rest are reviewing the idea of CPPSI membership. Additional funded projects related to the CPPSI mission will be submitted as grant proposals to CDFA Specialty Crops, the Seed Central Vegetable R&D Forum and for ASTA R&D funds.

A pricing structure and strategy for selling future disease sets was developed based upon calculations of actual effort and estimated costs to develop each disease set, the business plan survey results of what the seed industry members would pay for differential host seeds and strains and what MATREF - GEVES actually charges for differential seeds and strains. The pricing plan will be submitted to UC Davis university administration.

Proposed next steps for CPPSI

• Continued disease set development
• Continued fund raising
• Funded projects and services that align with CPPSI’s mission
• The addition of new sponsoring members
• EU partners and continued joint projects with ISF, NAKT and GEVES-MATREF
• Addition of new members to the CPPSI WG to support additional disease set development

ANNUAL REPORT 2015
Establishment of 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 serve as the director of the Seed Biotechnology Center. An endowment will ensure that the seed industry’s needs for academic research, education and public service can continue to be met. For more information or to contribute to our goal, contact Christine Schmidt at cmschmidt@ucdavis.edu.

Thank you to our generous endowment supporters in 2015!

American Takii

Growing strong! In March we were delighted to receive the first gift to the endowment from HM.Clause and Limagrain. Their generous gift of $500,000 was a very important start to the campaign. In 2015 we added numerous new gifts and will do so again in 2016.

Keithly-Williams Seeds

Kent & Barbara Bradford

The Plant Breeding Center (PBC) at UC Davis coordinates and expands plant breeding teaching and research on campus. We are focused on training graduate students to be well rounded, with experience in field-based breeding evaluation and techniques, supplemented with an understanding of and facility with modern genomics and phenotyping technologies. The PBC’s purview covers all crops grown in California and beyond, from nut and fruit trees to vegetable and agronomic crops, including both seed-propagated and clonal species. The PBC is working with the Graduate Group in Horticulture and Agronomy to develop a clear plant breeding coursework track and is currently devising a Graduate Academic Certificate in Plant Breeding. The PBC plans seminars and field trips to supplement plant breeding coursework by giving students real-world examples of the types of work available in both public and private sectors. They also seek funding to expand field-based plant breeding education and prepare graduate students for employment. In 2015, the PBC successfully obtained a USDA-NIFA National Needs Fellowship grant, which will train four exceptional women joining PBC graduate programs in Fall 2016 to be plant breeding leaders.

Comprehensive plant breeding education requires that students get experience in actual germplasm or cultivar development programs. One way to do this is through internships with breeding companies, and the PBC hopes to develop an expanded internship program in 2016-17. A second way is through activities within existing breeding programs on campus – UC Davis has a wide range of programs from walnuts to strawberries, wheat to beans, and many more.

Update from the UC Davis Plant Breeding Center
This year, the PBC obtained a nearly $1 million grant from the USDA-NIFA Organic Research and Education Initiative (OREI) to develop cultivars for organic vegetable production and, in the process, train students to develop and conduct actual breeding programs. As part of this project, the PBC is working with the Organic Seed Alliance and organic growers across California to set priorities and eventually trial new germplasm on-farm. As the project progresses, growers will evaluate germplasm and participate in breeding varieties that have the most desirable traits. Current plans include new varieties of tomato, pepper, common bean, and lima bean, with additional crops added in the future.

In order to continue training in field-based breeding and expand the scope of its public breeding projects across crops, the PBC needs to foster collaborations with the seed and nursery industry, commodity groups, and non-profit organization partners who are interested in either providing in-kind support to breeding programs or in directly funding research, including graduate student stipends, on a particular crop. The PBC is also developing an orientation to introduce incoming students interested in plant breeding to the plants currently being bred on campus, show them the many ways they can get involved with breeding projects on campus, and explain the long history of cultivar releases from UC Davis. This orientation will ensure that PBC students are well-versed in the breeding activities on campus and are prepared to represent the university in presentations and discussions with growers and industry members. If you have input on how the PBC can help you, please let them know. The PBC’s web site can be found at PlantBreeding.ucdavis.edu.

Another exciting development in 2015 is that the Center was pleased to announce that Dr. Allen Van Deynze was appointed to be the Associate Director. See Plantbreeding.ucdavis.edu/2015_feb.pdf.

### SBC Visitors

The SBC hosts numerous visitors. Many are from the global seed industry while others are from universities, government agencies and non-governmental organizations. The following list highlights a few examples of these diverse groups:

- Discussion about joint educational programs with delegation from Jiangsu Academy of Agricultural Sciences (JAAS), China.
- Discussion with Current U.S. Social, Political, and Economic Issues for Young European Leaders: A Regional Project for Europe GMO Safety and Perspectives.
- Workshop for: The Sub Union of Seed Industrialists and Producers from Turkey.

### Other Presentations and Outreach

Each year the SBC staff makes numerous presentations for diverse groups to discuss various topics related to seeds, biotechnology and agricultural research. Following are some examples from 2015.

#### Presentations: Allen Van Deynze

- **Breeding, Genomes, and Root Rot in Peppers.** University of Abomey-Calavi, Cotonou, Benin. June 26, 2015
- **The Spinach Genome.** Plant Evolution conference, Amsterdam, Netherlands, September 5-9, 2015
- **New Breeding Technologies — An Opportunity to Play.** American Society of Cereal Chemists, October 18-21, 2015

#### Presentations: Kent Bradford

- **Acceptance of Biotech Specialty Crops.** Webinar presentation sponsored by the American Chemical Society, AGRO division, April 1, 2015
- **Crop Improvement, Biotechnology and the Environment.** Invited keynote presentation, Santa Clara University Environmental Law Society 3rd Annual Symposium, Food Law & Policy: Current State of Food Labeling and GMO Law, Santa Clara University, Santa Clara, CA, April 2, 2015
Other Presentations and Outreach (continued)

- **Biotechnology and Food Safety.** Invited presentation, Western Food Safety Summit, Hartnell College, Salinas, CA, May 7, 2015
- Discussion on crop improvement with California Assemblyman Jim Wood and others, Woodland, CA
- **The Toolbox: Modern Plant Breeding Methods.** Invited presentation, Sustainability, Genetics and Future Cultivars, American Phytopathological Society Annual Meeting, Pasadena, CA, August 1, 2015
- **Seed Drying, Storage and Functional Ecology.** Invited presentation, Kings Park Botanical Garden, Perth, WA, Australia, October 19, 2015
- **Genetic and Molecular Mechanisms Regulating both Seed Dormancy and Flowering.** Invited seminar, School of Plant Biology, University of Western Australia, Perth, WA, October 23, 2015
- **Seed Technology for Farmer Prosperity and Food Security.** Invited plenary speaker, Indian Seed Congress 2015, Hyderabad, Telangana, India, October 26-29, 2015
- **Genetic and Molecular Mechanisms Regulating both Seed Dormancy and Flowering.** Invited seminar, CSIRO, Canberra, Australia, December 3, 2015
  
  **Presentation:** Rale Gjuric


Upcoming Conferences and Meetings

During 2015 the SBC was busy planning for these large conferences. Venues were selected, program started to be developed and venues and other arrangements were made. Save the dates for the following SBC hosted events:

**13th Annual Solanaceae Conference**
September 12 — 16, 2016, UC Davis, California

**Seed Central Vegetable Research and Development Forum**
November 9 — 10, 2016, UC Davis, California

**International Society for Seed Science Conference**
September 10 — 14, 2017, Monterey, California

Board and Committee Service

**African Orphan Crops Consortium**
Steering Committee — Allen Van Deynze

**American Seed Trade Association**
Innovation and Policy Committee — Kent Bradford, Allen Van Deynze
Innovation in Plant Breeding Working Group — Kent Bradford, Allen Van Deynze
Future Seed Executives — Susan DiTomaso
Intellectual Property Rights Committee — Allen Van Deynze
Management Skills Committee — Susan DiTomaso

**California Crop Improvement Association**
UC Advisory Committee to Board of Directors — Susan DiTomaso

**California Potato Research Advisory Board**
UC Liaison — Kent Bradford

**California Seed Association**
Industry Communications & Youth Committee — Susan DiTomaso
Plant Breeders & Biotechnology Committee — Kent Bradford, Allen Van Deynze
Vegetable and Flower Seed Committee — Kent Bradford, Allen Van Deynze

**Genome**
Journal Associate Editor — Allen Van Deynze

**International Seed Testing Association**
Advanced Technologies Committee — Kent Bradford

**National Association of Plant Breeders**
Eucarpia liaison — Rale Gjuric

**Plant Breeding Coordinating Committee**
Past chair — Allen Van Deynze

**SeedQuest**

**SBC’s latest news, announcements, courses and advice and support.**

**SBC in the News**

[facebook.com/UCDavisSBC/]

[SeedCentral.org]

[www.seedquest.org]
SBC Advisory Council

The SBC Advisory Council announced expansion of its membership. The SBC is grateful for their sage advice and support:

- **Phil Ashcraft**, Verdant Partners
- **Charlie Brummer**, UC Davis Plant Breeding Center
- **Jovan Djordjevic**, Bayer CropScience Vegetable Seeds
- **Rick Falconer**, Rijk Zwaan
- **Dan Gardner**, S&W Seed Co.
- **George Gough**, Monsanto
- **Gary Hudson**, Hudson & Associates, Inc.
- **Matthew Johnston**, HM-Clause

- **Francois Korn**, SeedQuest
- **John Palmer**, California Crop Improvement Association
- **Betsy Peterson**, California Seed Association
- **Howard-Yana Shapiro**, Mars, Incorporated
- **Chip Sundstrom**, FJS Consulting
- **Mary Wadsworth**, J.G. Boswell Company
- **Chris Zanobini**, California Seed Association
- **Jeff Zischke**, Sakata Seed America

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RESEARCH

Carrots

**Enabling genomic-assisted breeding**
SBC’s **Allen Van Deynze** continues to work with **Philip Simon** (USDA/ARS, Wisconsin) and an international industry consortium (**Bejo, Nunhems, Rijk Zwaan, Takii, Vilmorin, Monsanto, Carosem and Sumika**) to develop and apply new tools for carrot breeding. In 2015, the consortium focused on refining and completing a draft expanded genome of carrot by taking advantage of the UC Davis partnership with **BGI**. The genome sequence was completed in 2015 by integrating information from BAC-ends, anchoring to high density genetic maps and annotating the genes present. Several projects are already leveraging this resource. These include defining the domestication of carrots and the basis of color and B-carotene in carrot roots. The quality of the genome is one of the best to date. It will be published in 2016.

Cotton

**Development of a haploid induction system for cotton**
In collaboration with **David Tricoli** (UC Davis) and **David Stelly** (Texas A&M), the SBC is translating research developed in Arabidopsis in the **Simon Chan** lab (UC Davis) to cotton. Chan identified a specific
Development of a haploid induction system for cotton (continued)

chromosomal protein (CenH3) that can be modified to simplify the development of haploid plants. The SBC is taking a multipronged approach to develop a haploid inducer for cotton by incorporating the latest technologies.

Transformation efficiency in cotton is poor and limited to a few genotypes. 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 in cotton. The SBC is working with the Ralph M. Parsons Foundational Plant Transformation Facility to screen 50 diverse lines of cotton for transformation and regeneration efficiency. We are also using the two recently released G. hirsutum and diploid G. raimondii genomes to create CRISPR/Cas9 targets for gene editing of the CenH3 gene(s) in cotton. This research leverages seminal research by Anne Britt and Luca Comai of UC Davis. This work was funded by Cotton Incorporated.

Anchoring and characterizing variation in the cotton genome
In an effort to fully leverage cotton genomics for plant breeding, the SBC continues to work with David Stelly (Texas A&M) to anchor the genome(s) of cotton using high-density genetic maps. Rather than focusing on reduced-representation sequencing or specific markers, the group is using full genomic sequencing of an F2 population between G. barbadense (3-79) and G. hirsutum (TM-1). This project was expanded in 2015 to create an ultra-high density genetic map. Analysis is being carried out by postdoctoral fellow Amanda Hulse-Kemp. This work was funded by Cotton Incorporated.

Lettuce
Identification of genes involved in lettuce seed thermoinhibition
Germination of lettuce (Lactuca sativa) seeds is delayed or inhibited when planted at warm temperatures, leading to delays or failures in seedling emergence and resulting in yield losses and higher costs. The Bradford Lab, in collaboration with the Michelmore lab and USDA-ARS researchers at Salinas, has identified a new QTL and candidate gene associated with the ability of lettuce seeds to germinate at high temperatures. This QTL was fine-mapped and characterized by PhD student Fei-Yian Yoong, who completed her degree in March 2015. Working with a mapping population derived from a primitive Lactuca sativa accession (PI251246), Yoong that a gene involved in the action of ethylene (ETHYLENE RESPONSE FACTOR 1 or ERF1) is a likely candidate to be associated with germination thermotolerance (see Publications list on page 28). Near-isogenic lines containing this locus in a cultivated background (cv. Salinas) are available from the SBC. This research was supported by the National Science Foundation through the Compositae Genome Project.

Novel regulatory mechanism links seed dormancy and flowering times in lettuce
Postdoctoral scholar Heqiang Huo and visiting scientist Shouhui Wei working in the Bradford Lab discovered that a gene previously known to be involved in regulating seed dormancy (termed DELAY OF GERMINATION 1 or DOG1) is also involved in regulating seed thermoinhibition in lettuce and Arabidopsis. In addition, and
somewhat surprisingly, they also showed that DOG1 could also influence flowering times, as silencing of DOG1 expression caused earlier flowering in lettuce. Huo further demonstrated that the effects on both seed dormancy and flowering involved microRNAs (small, 21-nucleotide RNA molecules) that target specific transcripts for degradation. This work demonstrated that seed dormancy is a major plant developmental transition, and that the same underlying molecular system is involved in regulating both seed dormancy and flowering. The discovery could enable development of lettuce cultivars more resistant to bolting. This study will be published in early 2016 in the Proceedings of the National Academy of Sciences. This research was supported by the National Science Foundation, USDA-National Institute of Food and Agriculture, the China Scholarship Council and Natural Science Foundation of China, and Rijk Zwaan B.V.

Effects of maternal environment during seed development on lettuce seed thermoinhibition
As noted above, lettuce seeds are generally unable to germinate at warm temperatures. However, the upper temperature limit for germination is sensitive to the environment in which the seeds were produced: seeds matured at warm temperatures can germinate at higher temperatures than seeds matured at lower temperatures. Mohan Niroula, a PhD student in the Bradford Lab, has identified genetic loci associated with this environmental plasticity. He is working to fine map this locus and potentially to identify the gene(s) responsible for maternal effects on seed dormancy with the goal of making seed performance more consistent and less dependent upon the location of seed production. This work is supported by the Western Regional Seed Physiology Research Group, a collaboration of seed and seed technology companies (Ball Horticultural, Bejo Zaden, Chia-Tai, East-West Seeds, Enza Zaden, Germain’s Technology Group, HM.Clause, INCOTEC, Monsanto Vegetable Seeds, Bayer-Nunhems USA, Rijk Zwaan, Sakata Seed America, Seed Dynamics and Syngenta).

Identification of mutations affecting lettuce seed thermoinhibition by genomic sequencing
Postdoctoral researcher Heqiang Huo of the Bradford Lab collaborated with the Luca Comai Lab in the UC Davis Genome Center to test a new strategy to identify mutations affecting seed germination. Rijk Zwaan scientists induced mutations in lettuce and selected lines that resulted in germination at higher temperatures. Using a method called bulked segregant analysis (BSA), a segregating population of seedlings was separated into groups that either did or did not germinate at high temperature. Total genomic DNA from the selected pools was sequenced, and comparisons of differences in the sequences enabled the identification of the mutated gene that affected germination. Huo further confirmed that this was the causal mutation through gene isolation and transgenic functional tests. This project demonstrated that this BSA by sequencing approach was feasible for efficiently identifying specific mutations with a clear phenotype, even in plants with a large genome. This work was supported by Rijk Zwaan B.V.

Pepper

Defining genetic resistance to late blight and the basis of fruit shape
In an effort to develop acceptable bell pepper breeding lines conferring stable genetic resistance to late blight, Phytophthora capsici, the SBC has been working for the last 5 years on determining the genetic basis of resistance to the pathogen as well as the basis for fruit size and shape. A primary source of resistance is Criollos del Morellos 334, a landrace with poor growth habit, small triangular spicy fruit, but resistance to most P. capsici isolates challenging it. The vast majority of progeny
Defining genetic resistance to late blight and the basis of fruit shape (continued)

from crosses with small fruited lines and bell types are small fruited or lack the desired blocky shape. By screening with multiple \( P \) \textit{capsici} isolates and evaluation of over 600 recombinant inbred lines in the field for horticultural traits and fruit quality, the SBC has defined genetic determinants for these traits. It has also created advanced lines combining these traits. This work was supported in-kind by Enza Zaden B.V. and Rijk Zwaan B.V., the UC Davis Plant Sciences Department and a fellowship to Ph. D candidate Jareerat Chunthawodtiporn from the Government of Thailand.

Dissecting fruit shape and size
Senior research associate Theresa Hill of the SBC has created several populations in pepper that have simplified the genetics of fruit size and shape in pepper. Three F3 populations were evaluated in replicated trials for multiple measurements of fruit shape and fruit size by digitally capturing cross-sectional and longitudinal sections of fruit from each line. These traits are being genetically mapped to study the inheritance of these traits and provide genetic markers to efficiently trace these traits in breeding programs. Undergraduate student Juriaan Visser was part of the research team. This work was supported by Enza Zaden B.V and Rijk Zwaan B.V.

Determining the basis of plant regeneration in pepper
Doubled-haploid plants provide simpler genetics and can make breeding programs more efficient. They are pure breeding and can be produced in a single generation using various methodologies, including culture of pollen grains (microspores). In pepper, only certain lineages are amenable to this technology using anther culture. The SBC partnered with Rijk Zwaan to study the genetic basis of embryogenesis and regeneration of plants from microspores in pepper. The SBC assayed a large RIL population to correlate genotypes with phenotypes, including expression analyses, with the goal of identifying genes regulating embryogenesis and regeneration that may confer genotype specificity to anther culture in pepper. Several QTL and potential candidate genes have been identified for this important trait by a team including Theresa Hill, Tui Ray (Research Associate) and Alddo Chaverri (undergraduate student). Understanding these genes may allow for selection of amenable combinations to anther culture and production of haploids for breeding.

Understanding the basis of color in pepper
The SBC partnered with Ilan Paran (Volcani Institute, Israel) to identify the determinants of dark green fruit color in pepper. Initial research by Paran showed that at least two chromosomal regions control this trait. After publishing that the gene \textit{CaGLK} was responsible for the locus on chromosome 10, the team received funding to define the genes on chromosome 1. Field trials, metabolic profiles, Bulked Segregant Sequencing analyses and expression analysis are being employed in this project. Candidate genes are currently being verified by senior research associate Kevin Stoffel. A Binational Agricultural and Research and Development (BARD) grant was obtained to define candidate genes and interactions with this gene and the QTL found on chromosome 1 by Paran’s group.

Breeding for resistance to virus
The SBC is working with Robert Gilbertson (Department of Plant Pathology, UC Davis) and Jose Luna-Ruiz (Universidad Autonoma de Aguascalientes, Mexico) to screen a population of wild peppers (\textit{C. annuum} var \textit{glabriusculum}) for resistance to beet curly top virus.
Hundreds of crosses have been made to these landraces to evaluate their potential to confer resistance. Screening is being carried out using Agrobacterium inoculations and verified using the leafhopper vector inoculations. Lines showing resistance are being crossed to jalapeno varieties to introgress novel genes and alleles for resistance. This project is funded by a National Science Foundation fellowship to PhD candidate Randi Jimenez and the Department of Plant Sciences, UC Davis.

Developing a water-efficient pepper
The SBC is partnering with Eduardo Blumwald (UC Davis) to extend to peppers a technology proven to confer drought tolerance in peanut, rice and tobacco (Reguera et al., 2012). Expressing a gene that results in the production of the plant hormone cytokinin in response to stress has protected yield under water stress in several crops. In collaboration with the UC Davis Ralph M. Parsons Plant Transformation Facility, the SBC created the transgenic plants and is in the process of evaluating efficacy of this gene in pepper. As a basis for comparison, the physiological changes in pepper under water stress were characterized. This research is supported by a fellowship to Jaser Aljaser by the Government of Kuwait and the Department of Plant Sciences, UC Davis.

Seed ecology

Applications of population-based threshold models to seed ecology
The Bradford Lab has long been engaged in developing and applying mathematical models to describe seed germination behavior. These models describe the characteristics of seed populations and provide specific parameters to quantify seed dormancy and germination potential under different conditions. Shuangshuang Liu (PhD student) worked with colleagues Larry Venable at the University of Arizona, Zhenying Huang at the Institute of Botany at the Chinese Academy of Sciences and Travis Huxman at UC Irvine to apply this approach to germination data on a dozen species found in the Sonoran Desert. Liu was able to identify functional traits (i.e., speed of germination, sensitivity to temperature or water stress) that were highly correlated...
The UC Davis Child Family Institute for Innovation and Entrepreneurship Innovation Center projects test new seed technologies. Clear patterns of metabolite changes are associated with different amounts of several hundred metabolites. Dominique Ardura to analyze changes in the small metabolites and lipids that occur during seed germination or dormancy. Oliver Fiehn is partnering with Rijk Zwaan companies (Monsanto Vegetable Seeds, Technology Group, INCOTEC, HM.Clause, East-West Seeds, Bejo Zaden, Ball Horticultural) and is testing the capabilities of an instrument, the Astec Q2 (www.astec-global.com), that can measure the respiratory (oxygen consumption) patterns of individual seeds during germination. Pedro Bello (Staff Research Associate) has developed new ways to analyze this data that make the results more readily understandable and amenable to mathematical modeling analyses that are commonly applied to seed germination data (see Seed Ecology section above). We have demonstrated very close correlations between seed respiration rates as measured in the Q2 instrument and seed germination rates (timing) in response to temperature, water, respiratory inhibitors, aging and priming. This enables Q2 data to substitute for labor-intensive determinations of germination time courses to assay for seed vigor, aging and other applications. This research is supported by a consortium of seed and seed technology companies (Astec Global, Bejo Zaden, INCOTEC, Rhino Research, Rijk Zwaan, SESvanderHave and Syngenta).

Seed Physiology and Technology

Seed respiratory patterns during germination
As soon as they take up water, seeds begin to respire in order to generate the energy required to power germination. The Bradford Lab has been testing the capabilities of an instrument, the Astec Q2 (www.astec-global.com), that can measure the respiratory (oxygen consumption) patterns of individual seeds during germination. Pedro Bello (Staff Research Associate) has developed new ways to analyze this data that make the results more readily understandable and amenable to mathematical modeling analyses that are commonly applied to seed germination data (see Seed Ecology section above). We have demonstrated very close correlations between seed respiration rates as measured in the Q2 instrument and seed germination rates (timing) in response to temperature, water, respiratory inhibitors, aging and priming. This enables Q2 data to substitute for labor-intensive determinations of germination time courses to assay for seed vigor, aging and other applications. This research is supported by a consortium of seed and seed technology companies (Astec Global, Bejo Zaden, INCOTEC, Rhino Research, Rijk Zwaan, SESvanderHave and Syngenta).

Metabolomics of seed germination
The Bradford Lab is partnering with Oliver Fiehn of the West Coast Metabolomics Center at UC Davis to analyze changes in the small metabolites and lipids that occur during seed germination or dormancy. Dominique Ardura (PhD student) has sampled lettuce seeds at various times after imbibition and quantified amounts of several hundred metabolites. Clear patterns of metabolite changes are associated with different stages of germination and are altered due to thermoinhibition or the effect of the hormone abscisic acid. This project is supported by the American Seed Research Foundation.

Innovation Center projects test new seed technologies
The UC Davis Child Family Institute for Innovation and Entrepreneurship supports research programs that address and align with practical applications (gsm.ucdavis.edu/entrepreneurship). Supported by its Sustainable AgTech Innovation Center, the SBC is working with faculty colleague David Slaughter in Biological and Agricultural Engineering and with seed technology company AgInnovation (aginnovationusa.com) to further develop two new seed technologies. The first is a “seed tracer” project that would enable plants to take up a compound that would give a strong fluorescent signal that could be detected by a sensor on a tractor. This would enable robotic equipment to identify crop plants for thinning and distinguish them from weeds for mechanical weeding. Dr. Slaughter has developed such vision systems, and adding the seed tracer could make such equipment more efficient and effective. In a second project, we are working with the Centor Group and AgInnovation to introduce large-scale seed drying systems based on drying beads (see description on following page under Seed Storage). The “Flexi-Dry” system contains the desiccant beads internally and can generate continuous flows of low humidity air at any desired temperature. It regenerates the drying beads automatically, enabling simple operation and convenience for any application requiring safe drying, including after seed coating or priming. A pilot system will soon be available in California for demonstration. Contact Kent Bradford at kjbradford@ucdavis.edu for more information.
Application of Videometer to seed phenotyping
The Videometer is an instrument capable of illuminating and taking images with light of 19 different wavelengths (www.videometer.com). This provides an array of information about seed properties that can be used for phenotypic analysis, quality evaluation and sorting. The Bradford Lab has access to a Videometer and is exploring its capabilities. It can quickly measure metrics of seed size from a random sample, as Mohan Niroula (PhD student) has done for mapping populations of lettuce. Other breeding students have used it to assess cracks and disease or insect damage to bean seeds. We are exploring various ways to utilize the instrument to detect specific information about seeds that could permit sorting on multispectral criteria. We appreciate the generosity of Peter Marks of AgInnovation, who has loaned us a Videometer and is contributing support for investigating its capabilities for seed applications.

Seed Storage

Seed Systems project scales up novel seed drying and storage strategies for humid regions
Kent Bradford and Peetambar Dahal previously led a 3-year project to improve and disseminate a novel method for seed drying using desiccant Drying Beads®. The project was supported by the U.S. Agency for International Development (USAID) through the Horticulture Innovation Lab based at UC Davis. The project demonstrated that the Drying Beads® can be used to dry seeds to safe storage moisture contents even in rainy and high humidity climates. When combined with hermetic storage containers, the seeds also are protected from damage due to molds, insects and rodents. An extension of the USAID-Horticulture Innovation Lab project is currently enabling seed and food companies in Bangladesh install and utilize desiccant-based drying systems in their operations. Johan Van Asbrouck of Rhino Research in Thailand is leading the scale-up project, and project collaborator Keshavulu Kunusoth of the Professor Jayashankar Telangana State Agriculture University in Hyderabad, is also promoting the use of drying beads for seed drying in India. The project has also developed simple methods for determining seed moisture contents in the field and is promoting a “dry chain” concept for drying, packaging, transport and storage of seeds and dried commodities. For more information, see www.dryingbeads.org.

Drying methods affect potential seed longevity in storage
It has long been known that when seeds dry down, their moisture contents at a given relative humidity can differ from when the same seeds are absorbing water and increasing in moisture content. This “hysteresis” in seed moisture content-RH isotherms has seldom been considered in the past as being involved in seed storage. However, work in the Bradford Lab has found that seeds that are on their absorption isotherm store longer than do seeds on their desorption isotherm due to the lower seed moisture content of the former. This has implications for seed drying protocols, particularly for long-term germplasm conservation. Seed longevity doubles for every 1% decrease in seed moisture content, so large benefits in seed storage life can be realized by drying to lower moisture contents. This is facilitated by the availability of drying beads (desiccants) that can safely dry seeds to very low moisture contents without heat. The work also demonstrated that it is seed moisture content, not the equilibrium relative humidity, that is most critical for seed longevity. This work is supported by the Western Regional Seed Physiology Research Group, a collaboration of seed and seed technology companies (Ball Horticultural, Bejo Zaden, Chia-Tai, East-West Seeds, Enza Zaden, Germain’s Technology Group, HM.Clause, INCOTEC, Monsanto Vegetable Seeds, Bayer-Nunhems USA, Rijk Zwaan, Sakata Seed America, Seed Dynamics and Syngenta).
**Spider Plant**

**Collaborative breeding program for spider plant**

As a development of the African Orphan Crops Consortium, the SBC is a collaborator on a program led by Dr. Enoch Achigan Dako, University of Abomey-Calavi, Benin on participatory breeding of spider plant (*Cleome gynandra*) for resilience to climate and nutrition. Other collaborators include Eric Schranz, Wageningen University, The Netherlands; Edgar Deguenon, Hortitech Development, Benin; Andreas Ebert, AVDRC, the World Vegetable Center; Patrick Mando, KENRIK, Centre for Biodiversity, National Museums of Kenya, Nairobi, Kenya. Spider plant is a vegetable eaten as “spinach” in most countries in Africa. It is a C4 plant adapted to several environments including drought stressed areas. It is highly nutritious and a rich source of micronutrients and vitamins. It is eaten steamed or mixed into many dishes. This project is funded by the Dutch foundation NWO-WOTRO Science for Global Development.

**Spinach**

**Sequencing of the spinach genome**

Spinach production in California has increased steadily with the introduction of fresh market baby leaf products in the 1990s. This has also been accompanied by an increase in incidence of disease, including *Perozyospora effusa* (downy mildew), Fusarium wilt and Verticillium wilt. To develop molecular tools to address the challenges in controlling these pathogens, the SBC is utilizing the UC Davis Corporate Affiliates Partnership Program to partner with a consortium of Seed Central members and BGI to sequence the genome of spinach. Consortium members include Rijk Zwaan, PopFriend, Syngenta, Enza Zaden, Nunhems, Sakata Seed America and Takii. In 2013, the SBC completed sequencing and assembly of the spinach genome in partnership with BGI using Illumina technology. In 2014, the SBC led the field by being the first to sequence and assemble a complex plant genome using Pacific Biosciences SMRT technology. In collaboration with Pacific Biosciences and Michael Schatz (Cold Spring Harbor National Laboratory), the spinach genome was assembled, resulting in a 63-fold improvement over short-read methods. In 2015, the SBC’s Amanda Hulse-Kemp and Hamid Ashrafi (now faculty at North Carolina State University) focused on refining annotation and anchoring the genome with a high density genetic map. We expect to publish the genome in 2017.
Sunflower

Genomic tools for sunflower breeding
Sunflower is an important oilseed crop grown mainly in the U.S., Russia and Eastern Europe. Breeding for sunflower, like other crops, can be facilitated with genomics. High-density genetic maps based on microarray technology have been developed and a genome sequence is under way. In 2015, the SBC worked with Pioneer Hi-Bred to develop genomic tools related to yield in sunflower using a series of populations based on recombinant inbred lines derived from an American landrace. Funding for this work was from Pioneer Hi-Bred to support a PhD candidate Eric Hoefl (now a breeder with HM.Clause), who completed his PhD with Allen Van Deynze.

Tomato

Development of introgression and mutation populations
The SBC continues to collaborate with Roger Chetelat (Department of Plant Sciences and C.M. Rick Tomato Genetics Resource Center at UC Davis) and Luca Comai (UC Davis Genome Center) to develop and characterize a series of lines in tomato with segments introgressed from Solanum sitiens, a wild nightshade and distant relative that is only crossable using bridge-crossing techniques. This species confers several resistances to abiotic and biotic stress. This research is funded by the USDA National Institute for Food and Agriculture.

Also in collaboration with Roger Chetelat and Luca Comai, the SBC has expanded an induced mutant population in tomato to 4300 lines. A large number of phenotypic mutants have been observed in the population. Importantly, this population is available to the public to efficiently mine mutations at the DNA level using TILLING through the Comai Lab. This resource will serve the tomato community in determining the function of genes in tomato and provides the community with a rich source of novel alleles and phenotypes for breeding.

The SBC Research Team


SBC recognizes Dr. Peetambar Dahal

Dr. Peetambar Dahal, long-time Staff Research Associate with Kent Bradford, retired in 2015 after being at UC Davis since 1987. Raised in Nepal with a view of Mount Everest from his bedroom window, Peetambar completed his BS degree in India and worked as a seed official in Nepal before coming to UC Davis to do a MS degree in 1987. He continued for a PhD degree in 1994 and became laboratory manager with Kent Bradford the same year. Peetambar was involved in virtually all of the research projects in the Bradford Lab for the next 21 years. Following his retirement, Peetambar has continued to work on improving seed storage systems in Nepal and helping in recovery efforts following the devastating earthquake in April 2015. The SBC appreciates his long service to UC Davis and his contributions to seed science.
PEOPLE AND PUBLICATIONS

Scientific Publications by SBC Researchers


SBC Welcomes

**Phyllis Himmel** joined the UCD Seed Biotechnology Center in July 2015 to lead the seed industry funded Collaboration for the Identification of Plant Pathogen Strains (CPPSI). She brings 25 years of experience in disease resistance discovery and development, research leadership, product discovery and development in the Agricultural Sciences. Phyllis received her MS and PhD in Plant Pathology from the University of Arizona. After a 3 year USDA/ARS Post Doc researching WSBMV in hard red winter wheat at the University of Illinois, Phyllis joined the Asgrow (later Seminis, Monsanto) Vegetable Seed Company as a research pathologist. She established and led a program to identify and develop resistance in vegetables to viral pathogens, eventually leading the global pathology team of 64 scientists and staff as Director of Research Pathology. While at Marrone Bio Innovations, Phyllis held personnel and product management roles in the discovery and development of plant and microbe based biostatistics.

**Rebeca Madrigal** joined the Seed Biotechnology Center in April 2015. Her background includes providing program and analytical support to identify potential research collaborators and developing relationships with industry for the UC Davis Office of Research, InnovationAccess. As Program Representative, she is responsible for the oversight of various educational programs, meetings, events, conferences, marketing materials, website and the development of programs.

**Julie Tillman** brings to the SBC a diverse professional background encompassing both biological science research and computer/design technology. After receiving a PhD in Biochemistry from the University of Nevada and postdoctoral positions at the Universities of Nevada and Minnesota, she pursued a long-held interest in web technology. In 2002 she launched web site design and management sole proprietorship TillSey Web Design, where she developed and managed web sites for clients throughout northern California. Since joining the SBC in the spring of 2015, she has provided the center with general computer and technology support, including graphic/print design, web site management, videography, and photography. She will also be assisting center staff with event, course, and conference coordination and management.
SBC Team

Allen Van Deynze
Research Director

Joy Patterson
Program Representative

Julie Tillman
Program Representative

Kent Bradford
Director

Phyllis Himmel
CPPSI Director

Rale Gjuric
Education Director

Rebeca Madrigal
Program Representative

Sally Mohr
Program Representative

Susan DiTomaso
Associate Director
PARTNERSHIPS FOR THE FUTURE

Strange Bedfellows:
The Planet’s Desperate Need for Uncommon Collaborations

A message from Howard Yana Shapiro

Many, many uncommon collaborations will be needed to manage the grand challenges threatening our civilization.

Climate change, for example, is not one phenomenon; it is a system of causes and effects (energy use, agriculture, water management, climate change, sea-level rise, ocean acidification, deforestation, extreme weather events), and its management will require a systemic approach designed by the best and the brightest from government, academia, business and civil society.

What is an uncommon collaboration? Here is a narrower example. When Mars, Incorporated set out to sequence the cacao genome, we realized that no single organization had the skills needed. So we worked with academia (Clemson University Genomics Institute, to name only one), other companies (IBM and government bodies (USDA Agricultural Research Service). The recent, successful effort to sequence the peanut genome used the same sort of odd alliance, but on a global scale.

Mars is famous for producing candy and pet food. How could such a company help to feed the world, especially the planet’s hungriest? In fact, Mars is very good at managing complex supply chains and producing and delivering safe foods in difficult environments. This is why the UN Food and Agriculture Organization reached out to solicit Mars’ help in developing inclusive and sustainable agricultural systems and to contribute to global food safety. The goal is to enhance opportunities for safe, local sourcing to increase small farmers’ productivity and income. The World Food Programme provides food in international emergencies. It has asked Mars to help it establish processes that guarantee food quality throughout the supply chain. Neither of these organizations needs Mars the company, but they need certain skills Mars has developed as a company, skills that do not reside in academia, government or nongovernmental organizations.

When Mars established the African Orphan Crops Consortium to sequence the genomes of 101 African home garden food plants, we looked for the very best partners. So we chose the Seed Biotechnology Center. The UC Davis Plant Breeding Academy produced the curriculum for the Consortium’s African Plant Breeding Academy, which we have based at the World Agroforestry Centre, the best organization of its type on the planet.

I believe firmly in Joy’s Law, the idea that “no matter who you are, most of the smartest people work for someone else.” Sun Microsystems co-founder Bill Joy further argued that “it’s better to create an ecology that gets all the world’s smartest people toiling in your garden for your goals. If you rely solely on your own employees, you’ll never solve all your customers’ needs.” In fact, if we rely only on people from one sector of society, we will be defeated by the planet’s big problems.

Yet we seem to live in fractious, divisive times. These fractures are not only political and ideological, but often divide key societal sectors, making government, business, academia and civil society increasingly suspicious of one another.

However, I would argue strongly that these suspicions occur mainly among the less experienced and less talented, those less able to help with the big problems. Narrow-minded people by definition have trouble collaborating.

The best and the brightest are not only those most able to work with other sectors, they are the ones best able to understand the importance of doing so. In fact, the best probably have had careers that have included stints in government, business, academia and civil society. Examples abound, but for one take Carl Schramm, a leading global expert on innovation. He has founded several healthcare, finance and information technology companies. He has worked with governments, from the US to Singapore, and he has been associated with top universities. He is a walking uncommon collaboration.
Mars and UC Davis are collaborating on a new Innovation Institute for Food and Health on the Davis campus. The goal is to bring academia, industry and the community together to accelerate innovation, rather than letting them work separately and then trying to fit the pieces together. Such centers and institutes are becoming more common, pushing academia beyond focusing on research alone and into collaborative research and development that leads to revolutionary new goods and services.

Politics makes strange bedfellows. So do crises. Shakespeare may have invented the expression when he wrote in The Tempest, “Misery acquaints a man with strange bedfellows.” Uncommon collaborations are the most effective way of managing crises and breaking out of miserable times by getting all of the world’s smartest people toiling in the same garden for the right goals.