



Annual Report

2020 - 2022

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An annual report is time to take stock and recognize what has been done and also helps to focus on what can be done. This one runs way back and it seems like it began when the world was normal and SBC was firing on all cylinders in outreach, education and research with all of its classes in-person and well-subscribed. Its Plant Breeding Academies were on three continents and in-house programs on Seed Business to Seed Production, and Seed Central were well attended with research well funded on diverse areas important to California and global agriculture. Rale Gjurić continued to lead the education program until July 2020 when he retired after 10 years of building it. Rale elevated the SBC's educational programs and was recognized internationally as a SeedWorld Giant in the industry for his impact in training thousands of professionals worldwide. His knack of being able to convey complex quantitative formulas into practical uses in breeding has laid the foundation for all of our classes. We thank Rale for all of his dedication and making it fun along the way.

We were very fortunate to have yet another “Giant” in the plant breeding industry join us in September 2020 to lead and teach our Plant Breeding Academies and classes. Jovan Djordjević brings decades of experience in leading programs in both field-based (corn and canola with Monsanto) and vegetable crops (HM.CLAUSE and BASF Vegetable Seeds) to the role of Director of Education. Unfortunately, nothing was the same for Jovan in 2020. This did not deter. Based on an industry-wide survey, Jovan rebuilt the SBC education programs by developing online classes complementary to our in-person classes from the ground up. This not only kept us visible, but significantly expanded our reach internationally across time zones. Our in-person classes continued with new pandemic precautions when it was safe to do so (see Education). We are in great hands under Jovan's direction.

Imtiyaz Khanday joined the SBC as Assistant Professor of Plant Sciences and Director of Research of the SBC in July of 2021 (see Personnel section).

Seed Central also went online and international with the continued persistence and ingenuity of Francois Korn. Seed Central EXPRESS allowed us to not miss a monthly meeting. It also allowed access to panels of speakers and attendees worldwide. Seed Central expanded its interaction with students by offering online company visits and recruitment and career events including programs with the American Seed Trade Association, National Association of Plant Breeders and Crop Science Society.

Our research certainly slowed, but being an agricultural institution deemed essential, UC Davis was the only UC campus allowed to stay open throughout Covid, with safety precautions of course. As part of our outreach and commitment to the seed and plant breeding industries, I have spent a good deal of time with the National Association of Plant Breeders (NAPB) as vice-chair and now chair of its Borlaug Scholars program. This program, founded by Donn Cummings, long-time corn breeder for Monsanto, raises funds to mentor undergraduate and graduate students and recruit them into the plant breeding industry. As of end of 2022, 85 students had attended the annual meeting (virtually in 2020-2021), including discussing plant breeding with World Food Prize recipient and friend of the SBC, Dr. Gurdev Khush. This program was led by Don Jones (Chair, Cotton Inc.), myself (vice chair) and Sarah Potts (Secretary, Corteva) in 2020-2021. In 2022, positions moved up and Chandler Levinson (UC Davis) joined as Secretary.

I also work with the American Seed Trade Association (ASTA) on its emerging issues committee, which focuses on promoting

plant breeding and plant breeding tools such as gene editing. As most of you who know me are aware, this is something that I am passionate about and take every opportunity to make these tools available to all breeders from small to large companies and public scientists. We started in 2020 with an all-day event for legislators and regulators (USDA, EPA, and FDA) in February 2020 in collaboration with ASTA and NAPB, followed by talking to food manufacturers in the next month. Gene editing is a powerful tool that is democratizing biological science across the world. Its brilliance is due to the fact that modifications are targeted to specific genes or areas of the genome, making it (much) more efficient than transgenics. Small modifications can lead to marked improvements in traits, just like plant breeding. In fact, the majority of edits today cannot be distinguished from plant breeding.

That is the very premise that we are presenting and asking governments to consider while regulating (or not) this essential tool for plant breeders. Gene editing has stimulated innovation from scientists worldwide, such that it is hard to keep up with what is the latest addition to the toolbox. It is not limited to simply modifying genes, but also enables inserting many genes at one target location in the genome. This is a plant breeder's dream by allowing, for example, several favorable genes/alleles to be expressed as a single locus, significantly improving the efficiency of plant breeding to deliver solutions to feed a world with increasing pressure on population and environment. Now this sounds like something in movies, but already in 2017, the USDA (Albany, CA) showed that they can deliver 25 genes at once into a single locus in plants.

How should this technology be regulated, if separate regulation is necessary beyond current seed laws? We now know that a single variety may have hundreds of additional genes or many

copies of genes relative to another variety of the same species. We are finding these in every species we sequence, showing that certain pathways have multiple copies of genes that define the species, e.g. the oil and fatty acid pathways are amplified in Shea, while glucosinolate pathways have multiple copies of genes in Moringa. My favorite example of large DNA differences is in sweet peppers, which are missing 2500 base pairs (size of a gene) in the capsaicin synthase gene that is essential for spiciness in peppers. The good news is that USDA has exempted certain gene editing modifications from full regulation and has modernized its review process to be more efficient. Other governments have followed the lead, for example Kenya, Brazil, Argentina and Japan are releasing gene-edited products.

As I write this, there are 25 applications to the USDA for biotechnology products, 7 from multinationals, 13 from medium-sized companies and 5 from public institutions. We have not seen this level of innovation in biotechnology for 20 years. The first product through the USDA Regulatory Status Review was indeed a purple tomato developed at the John Innes Center in the UK and Norfolk Plant Sciences in Davis. I was fortunate to taste this high-antioxidant tasty salad tomato. It is fitting that a tomato variety was the first vegetable through the revised regulatory process, as the first USDA-approved crop was the FLAVR SAVR tomato from Calgene, a small company in Davis back in 1994. The future is bright for our industry, we just need to make sure it happens. I hope you enjoy our report.



Allen Van Deynze

Seed Biotechnology Center
Director



NEW DIRECTOR OF RESEARCH AND FACULTY MEMBER

The SBC is very happy to announce that we now have a new Director of Research at the SBC, Dr. Imtiyaz Khanday, who is continuing the work on seeds as a propagule begun by Kent Bradford. Imtiyaz is an Assistant Professor of Plant Reproductive Biology in the Department of Plant Sciences at UC Davis and an Assistant Agronomist in the Agricultural Experiment Station. Imtiyaz grew up among the highest mountains in the world in the Kashmir valley in India and received his M.S. in biotechnology from the University of Kashmir. He then moved to the Indian Institute of Science in Bangalore, India for his doctoral degree in plant molecular biology and genetics. He then was a postdoctoral researcher in the Sundaresan Lab at UC Davis, investigating the role of parental gene expression during zygotic development. There, he translated the scientific understanding of zygote development into a method for engineering apomixis, or asexual reproduction through seeds, in rice plants. Imtiyaz will continue his research in apomixis and extend it to other crop plants. He is also interested in understanding cell-fate determination during embryogenesis in cereal crops and also exploring seed vigor enhancement in tomato. This position was previously held by SBC founding Director and Professor Emeritus, Dr. Kent Bradford. Following Dr. Bradford's retirement, the position was moved to the top of the faculty recruitment list thanks to seed industry support via the SBC Seed Advisory Board.



Director
Allen E. Van Deynze, Ph.D.



Director of Education
Jovan Djordjevic, Ph.D.



Director of Research
Imtiyaz Ahmad Khanday, Ph.D.



Director of CPPSI
Phyllis Himmel, Ph.D.



Program Manager
Whitney Lowe



Program Manager
Jeffrey Robinson



Director Emeritus
Kent J. Bradford, Ph.D.

**OUR
SBC
TEAM**

EDUCATION







*Plant Breeding
Academy*SM



UCDAVIS

The European Plant Breeding Academy

is a premier educational program designed to train outstanding employees whose companies wish them to advance as professional plant breeders.

Jovan Djordjevic (left) and Rale Gjuric (right) passing of the gavel (banner)

CHANGE OF LEADERSHIP IN EDUCATION

Rale Gjuric, former director of our education programs, retired on July 1st, 2020 after 10 years with the SBC. Rale was instrumental in developing our professional programs and, in large part, for their success. Rale brought the business model for the programs along with decades of experience in plant breeding. He is a natural instructor who not only taught the concepts, but always translated how to bring them to practice. This is the foundation of all of our professional classes. Rale co-developed and taught courses for our Plant Breeding Academies (now on four continents), Management of Plant Breeding Programs, Seed Business, and Seed Production classes. He will be dearly missed, and we wish him the very best.

We were very excited to announce that Jovan Djordjevic joined SBC as Director of Education and Plant Breeding Academy Director in 2020. In addition, Jovan is leading and teaching in our professional classes. He was the Global Lead of Plant Breeding for BASF Vegetable Seeds for the previous 8 years and has 20 years of experience as a corn and canola breeder with Monsanto in France and Canada. Jovan is known for his development of plant breeding programs and mentorship of employees. He has been an advisor for the SBC since 2012, thus knows the SBC and UC Davis well. He came at a challenging time during the pandemic, but found a way to continue with the current course portfolio and to further develop our programs. We have been working to develop additional classes in plant breeding, statistics, experimental design and seed production online to complement our in-person classes. We have responded to a stakeholder survey that we conducted in 2020 to ensure that our programs continue to align with industry business needs and we continue to be very active in the seed industry.

UC DAVIS 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 400 breeders from 68 countries.

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 updates that address the most recent developments in plant breeding theory and practice.

In 2020, Jovan Djordjevic took the lead for the Plant Breeding Academy and is a key instructor for the Davis and European PBA and other courses for the SBC. Rita Mumm remains the Director of the African PBA. The core instructors include internationally recognized experts in plant breeding and seed technology. These instructors are supported by a number of guest lecturers from the private industry and academia. The structure of the program continues to use a proven model of in-person classes integrated with discussion and field trips.

INSTRUCTORS

Kent Bradford (UC Davis)

Allen Van Deynze (UC Davis)

Rale Gjurić (UC Davis)

Jovan Djordjevic (UC Davis)

Rita Mumm (University of Illinois)

Todd Wehner (North Carolina State University)

Iago Hale (University of New Hampshire)

Bruce Walsh (University of Arizona)

Rob Dirks (Consultant)

Alexandra Tomerius (AIB)

Kendra Armstrong (AbacusBio)

Jay Patel (Corteva, retired)

Ken Owens (Magnum Seeds, retired)





● - Countries for students that graduated from PBA



EPBA Class VI in Angers, France

PBA Classes turned online during the peak of the pandemic in 2021 and resumed to in-person in October 2021

After the PBA Europe Class VI of 17 professionals held its first session in October 2019 in Gent, Belgium, the class was postponed due to the pandemic and later resumed online in Spring 2021 when the class attended their second and third sessions.

The European Plant Breeding Academy Class VI students and instructors were excited to meet in person in Angers, France in October 2021. Academy instructors included SBC Director of Education Jovan Djordjevic, SBC Director, Allen Van Deynze, and Alexandra Tomerius. As a confirmation of the importance of in-person education for advanced classes, when the final session for PBA Class VII at UC

Davis was postponed due to the pandemic, the class chose to wait to continue their PBA class in-person, which was completed in Davis in 2022. The new PBA Class VIII at Davis was postponed until February 2022 (vs September 2021) and according to our director of education Jovan Djordjevic, “The UC Davis Plant Breeding Academy teaching model is focusing on the practical application of breeding science and theory and is taught by veteran instructors from industry and academia. We use an in-person teaching model that encourages exchanges in and out of the classrooms, and transfer of our instructor experiences to our students as well. In-person interactions are particularly important for the start of the class, where students meet with our instructors for the first time. Therefore, to allow all PBA VIII students more time to safely arrange travel after the pandemic and participate in person, the start of the PBA Class VIII was postponed until February 7-12, 2022.” The course is fully subscribed with 20 students from 6 countries.



African Plant Breeding Academy (AfPBA) resumes

After a postponement of 2 years, we were very happy to launch our Class V of the African Plant Breeding Academy at CIFOR-World AgroForestry in Nairobi in May and Dec 2022 to advance their plant breeding skills with the applications of genomics and the latest strategies in commercial plant breeding. The class is made up of 40 PhD professionals from National Programs in 21 African countries. Nineteen women are participating in the program led by Rita Mumm and supported by Bruce Walsh, Iago Hale, Todd Wehner and Allen Van Deynze.

PBA E-Series: short two half-day courses

Based upon a seed industry-wide survey assessing continuing educational needs during the pandemic, SBC launched online short courses called the PBA E-Series. This series utilizes an online format with the proven teaching models of our in-person courses, which focus on practical application and interaction with experienced instructors. The PBA E-Series short (two half-day) courses were offered online, via Zoom, for both the European and Pacific time zones. Courses included: i) Statistics & Experimental Design foundational level with core instructors Alexandra Tomerius, Iago Halo and Jovan Djordjevic; and ii) Hybrid Breeding Strategies with core instructors Ken Owens and Jovan Djordjevic. Both E-Series courses concluded with a panel discussion that included additional experienced guest breeders to help students answer critical questions during Q&A and get their different points of view: Manuel Rosas (BASF) and Hans Kampmann (Veginova)

These E-Series turned out to be quite popular during (and after) the pandemic and in only two months with two E-Series in two time zones, we attracted 200+ students across the globe, from Australia, Austria, Brazil, Canada, China, France, Guatemala, Hungary, India, Italy, Japan, Mexico, The Netherlands, South Africa, Spain, Switzerland, Tunisia, Turkey, UK, and the USA.



SBC EDUCATIONAL COURSES

SEED BUSINESS 101 2021-2022

This one-week program is designed to expose participants new to the seed industry 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 class is taught by widely respected industry executives with the additional help of experts participating as guest speakers. More than 600 participants have completed this course since 2010.

In 2020, both the Field Crop SB101 and the Horticulture SB101 were postponed. SB101 Horticulture resumed in person in December 2021 with a sold-out class of 35 students, and was held in 2022 with a record 42 students. It was taught by Mike Pereira (Granum Services LLC), David Armstrong (current Sakata CEO), John Schoenecker (HM. Clause, retired), and Jovan Djordjevic. We had plenty of guest presenters who volunteered their time and share their experiences, just to name a few: Andre Cariou (AG), Wayne Wiebe (HM.Clause), John Palmer (California Crop Improvement Association), Pedro Bello (UC Davis Bradford Lab), Elina Nino (UC Davis entomologist).

The SB101 Hort class in 2022 had an exciting group of 42 students from 17 companies with great interactions amongst them as they worked their way through four case studies and a rebranding exercise that put them into the

driver's seat of how a seed company successfully does business. Energy and enthusiasm are infectious!

TESTIMONIALS

"For me was a game changer. To have the opportunity to learn and participate in the whole process of a company is certainly something unique. And even better to share the experience with people from all the areas of the seed business."

- **Sergio Cabello Leiva**, Antufen Seeds Ltda

"I recommend the course not only to employees new to the business but also to the ones who need to see the whole flow of the seed business. Doing our daily job, we usually don't have a chance to have such a good summary, that intense and focused."

- **Esin Tunckol**, HM.Clause, Inc.

"This course has provided an excellent opportunity to see and understand how a seed company works, including the dynamic and diverse teams and problems that are involved. I now have a much clearer picture of my future role in the seed industry."

- **Brennan Hyden**, Cornell University



SEED PRODUCTION 2020-2022

This 3-1/2 day course, held in February 2020, in Davis, CA, 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 course remains in high demand. The 61 participants represented 14 countries and over 40 companies with regional, national and international reach. Instructors were Kent Bradford, Rale Gjuric (UC Davis), Mike Pereira (Granum Services), and Greg Welbaum (Virginia Tech).

The SBC offered its Seed Production course online over six 1/2 days in both 2021 and 2022. Taught by experts from both industry and academia, this 2021 course generated wide interest from all around the globe, drawing 97 professionals from the U.S., U.K., Australia, Brazil, Canada, Chile, Costa Rica, France, Germany, Guatemala, Hong Kong, India, Italy, Japan, Lebanon, and Mexico. Core instructors included Mike Pereira (Granum Services), Kent Bradford, and Jovan Djordjevic (both UC Davis).

This course had many guest presenters too: John Snelling (Rogue Seed), Tye Anderson (Sakata) Patty Buskirk (Terra Organics), Lindsey du Toit (Washington State University), Rale Gjuric (Farmers Business Network), Dave Mardesich (Sakata), Elina Nino (UC Davis), and Jim Schweigert (Gro Alliance).

TESTIMONIALS

"Thank you for the wonderful course. It was a great opportunity to listen and learn from such dedicated and knowledgeable people." - **Simon Lancaster**, Tozer Seeds Ltd.

"I really enjoyed your wonderful lesson! I learned many things from all of the instructors and I was able to reconfirm that I love this job." - **Min Sai**, TAKII & Co., Ltd.

"Great course, thank you. The 3 am start time (Australian time zone) was worth it!!" - **Chris Smith**, Sunland Seeds P/L

"The organization team did a fantastic job with the course! I will definitely recommend this course to others in my organization" - **Pat Battonyai de Oliveira**, Bayer



ASTA AND UC DAVIS SEED BIOTECHNOLOGY CENTER OFFERED SEED PRODUCTION SEMINAR FOR EAST AFRICAN AUDIENCE

The American Seed Trade Association and the SBC offered the Seed Production course online for an East African audience in April 2021. It was attended by 20 governmental and industry participants from Kenya, Rwanda, Uganda, and Tanzania. The seminar was attended by 20 representatives, including the Director General of the Ministry of Agriculture in Rwanda, and various seed production companies. The course covered introductory technical vegetable and maize seed production concepts and was held online with the following Instructors from the US: Mike Pereira (Granum Services), Kent Bradford, and Jovan Djordjevic (both UC Davis). This course had many guest presenters, too: John Snelling (Rogue Seed), Tye Anderson (Sakata), Patty Buskirk (Terra Organics), Lindsey du Toit (Washington State University), Rale Gjuric (Farmers Business Network), Dave Mardesich (Sakata), Elina Nino (UC Davis), and Jim Schweigert (Gro Alliance).

LEADERSHIP PROGRAM FOR PLANT BREEDERS AND SCIENTISTS 2022

A diverse class of 32 plant breeders and scientists from 11 countries, 25 seed organizations, across continents completed the UC Davis Seed Biotechnology Center Leadership program for Plant Breeders and Scientists (LEAD), a course taught annually in-person at the Davis campus. A former Management Program for Plant Breeders has grown into LEAD and is extended to 3 full days with added interactive case studies.

The course was taught by the SBC team of instructors and guest presenters. Jovan Djordjevic commented: "Today Plant Breeding isn't a one-person show anymore. Many more scientific disciplines have been added, a lot more stakeholders within and outside of a Seed Company to interact with, and that coupled with climate change and growing human population challenges, requires plant breeders and scientists to have strong leadership skills, as well. This course is redesigned to unlock the innovation power of plant breeding programs, with critical breeding insights as well as the soft skills toolbox needed to create high-performing teams and influence large numbers of stakeholders during development of new and improved varieties". Our model of "100 years of experience in the classroom" featured our new Lead Instructor Francois Lallouet, founding Lead Instructor Fred Bliss, Manuel Rosas, John Schoenecker, and Jovan Djordjevic along with guest presenters Amanda Papas, Ken Owens and Ludwig Hernandez.

Our SBC program manager, Jeff Robinson, made sure the experiences of both instructors and students, and the course itself, were at the highest level possible. We are particularly proud of this class, as it was one of our most interactive, with many exchanges with our instructors and among student participants, all conducive to great learning experiences. The UC Davis team wishes all our students success in their professional and personal endeavors. Due to the popularity of this course, we are reviewing possibilities with our partners for African and European editions.

HEMP BREEDING AND SEED PRODUCTION

In response to a growing industry and need, the SBC 2020 and 2021 editions of Hemp Breeding and Seed Production course took place online via Zoom due to the pandemic, welcoming a total of 93 students. It was designed to enhance the knowledge of professionals working on hemp improvement and propagation. The course covered hemp seed production topics such as flowering, pollination, seed development, harvesting and certification.

Course participants also learned about hemp genomics, genetics, sex expression and types of cultivars with corresponding breeding schemes and intellectual property protection options. Moderated by Jovan Djordjevic, instructors included an array of seed industry professionals: Kent Bradford, Charlie Brummer, Rale Gjuric, Allen Van Deynze, John Yoder (all from UC Davis), Chris Holly and Daniel Knauss (Cooley LLP), John Palmer (California Crop Improvement Association), K. Bear Reel (Charlotte's Web, Inc.), Lawrence B. Smart (Cornell University) and Nicholas Stromberg (Beacon Hemp).



DIVERSIFYING PLANT SCIENCES EDUCATION

Over 45% of California High School seniors identify as LatinX/ChicanX in California. Only one-half of that proportion makes up undergraduate students in the College of Agricultural and Environmental Sciences at UC Davis and only 13% of this demographic is represented at the graduate level. To begin to address this inequality, Allen Van Deynze is leading a grant with Charlie Brummer, Gail Taylor, and Dan Potter (all UC Davis) to provide scholarships for 7 California LatinX/ChicanX students in the Plant Sciences undergrad program. This includes mentoring, career development and networking programs to ensure their success.

NEW FEATURES ON OUR WEBSITE

EDUCATION TAB

Aligned with our vision for continuous education, the SBC and Plant Breeding Academy educational programs continue to be highly visible in front of our seed industry professionals. We want to be the main partner and first place to go for our customers and their employees' continuous learning and development programs. We have organized all of our educational programs into the Education Tab on our website. This likely will become the most popular page of our website www.sbc.ucdavis.edu. It is targeted toward seed industry leaders, managers, HR talent developers, breeders, scientists, and all industry personnel and experts looking for continuous learning and development.

CAREER TAB

With the demand for plant breeding professionals (breeders, pathologists, scientists, associates, assistants, technicians, greenhouse/farm managers, etc.) at an all-time high, the UC Davis Plant Breeding Academy and SBC have created an online Plant Breeding Careers webpage (Career Tab) to better connect industry and public personnel at the global level. Please send any available positions you wish to fill from both local and global talent pools to sbc@ucdavis.edu.

KENT J. BRADFORD ENDOWED CHAIR IN SEED SCIENCE

The 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. 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. We aim to reach \$2,000,000 as our goal for a permanent professorial Chair in Seed Science. We express deep appreciation for the many visionary supporters who have contributed: HM.CLAUSE, Inc., Sakata Seed America, Inc., Chia Tai Company, East-West Seed International, Syngenta Crop Protection, LLC, American Takii, Inc., Clover Seed Company, Ltd., Enza Zaden Research USA, Inc., Known-You Seed America Corporation, Rijk Zwaan USA, Inc., Takii & Co., Ltd., Keithly-Williams Seeds, The Kraft Heinz Company, Incotec, Inc., MaxField Genetics, Murray Gardner, and SynTech (Khosro Khodayari).



To donate please visit: <https://give.ucdavis.edu/APLS/123403>

CHANGE IN EDUCATIONAL PROGRAM SUPPORT

Many staff changes also came in 2020-2021, with Joy Patterson, Julie Tillman, Kelsey Maher and Rebeca Madrigal leaving us. Joy supported the Plant Breeding Academies for 11 years in Davis, Europe and Asia, making sure that all students and staff had to do was show up. Program support always received high marks on our post-class surveys. Julie supported various programs for the SBC including short courses, conferences, Seed Central and communications for 7 years. Similarly, Kelsey (2 years) and Rebeca (4 years) supported short courses and the African Plant Breeding Academy. We appreciate their many contributions to the SBC and wish them well in their new endeavors.

We were very pleased to welcome Whitney Lowe to the team in 2021. Whitney hit the ground running with years of experience in several industries as an event planner and manager and is supporting the Plant Breeding Academy programs. Jeffrey Robinson joined the SBC in 2022 to round off our education team supporting the short course programs. Jeff brings a marketing background to the team. Both have adapted well to our full-time online and in-person course agenda, making it look easy.



Joy Patterson



Julie Tillman

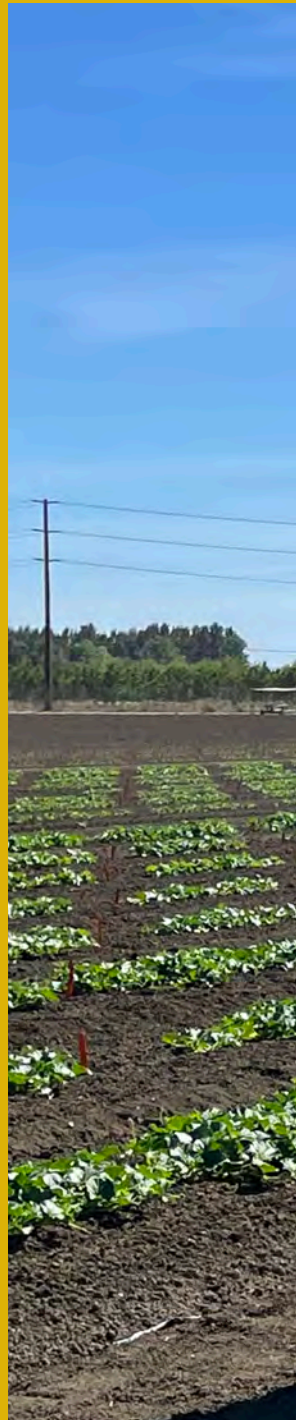


Kelsey Maher



Rebeca Madrigal

OUTREACH & PUBLIC SERVICE









Francois Korn
Co-Founder &
Managing Director

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, the approximately 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-five 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 2,000 participants from over 350 companies and organizations from California, the U.S. and overseas having attended these events. Seed Central events took place in January and February 2020 in-person then had to come to a halt, like many in-person social events. However, COVID-19 did not prevent Francois Korn from

bringing the industry together, for despite not being able to safely meet in-person as he had done for years, Francois and SBC quickly put together an online format to offer the same high quality presentations. The new event was rebranded Seed Central EXPRESS. It resumed in-person events in March 2022. On May 26th we introduced Seed Central Webinar Series with Kent Bradford's 1st installment: Understanding populations: implications for breeding vs. seed biology/technology. Subsequent installments occurred on September 29 and November 17. Two of the popular innovator showcases were also held in 2022. Save the date on 2nd Thursday of the month for Seed Central!

CORPORATE AFFILIATES PARTNERSHIP PROGRAM

Our Corporate Affiliates Partnership Program (CAPP), called the Plant & Seed Sciences Partnership Program (PSSPP), is coordinated by the SBC within the College of Agricultural and Environmental Sciences at UC Davis. CAPP is an established university model to facilitate research agreements and interactions between stakeholders, SC members, and the university and has remained vibrant since its inception in 2012, facilitating over \$3 million in collaborative research funding. The CAPP program continues to add collaborative research programs annually.

2020-2022 SEED CENTRAL PRESENTERS AND TOPICS

2020

January

4th INNOVATORS SHOWCASE

at UC Davis, featuring startups and innovative companies in seed, ag, agbiotech, microbiome, and food & health

Brought to you by:

UC DAVIS
Innovation Institute for Food and Health

UC DAVIS Microbiome Special Research Program

UC DAVIS
Venture Catalyst

February

THE FORUM

Networking event with featured speakers:

Jim Dong, Managing Director at *Amerland Seeds*

Jennifer Romero, Senior Environment Scientist at Cali. Dept. of Food & Agriculture

Albre Brown, Plant Pathologist, Cali. Dept. of Food & Agriculture

Gastón Salinas, CEO at Botanical Solutions

Olga Dubey, Founder & CEO at AgroSustain

Dr. Kirstin Bett, Professor, Pulse Crop Breeding and Genetics, University of Saskatchewan -
“Adapting lentil to new environments”

May

Markita del Carpio

Landry, Assistant Professor, Department of Chemical and Biomolecular Engineering, UC Berkeley

“Nanomaterials enable delivery of genetic material without transgene integration in mature plants”

September

PANEL

“New Breeding technologies for quality, nutrition and indoor farming” featuring **Vonnie Estes**, VP of Technology, Produce Marketing Association; **Emma January**, Senior Scientific Manager, Benson Hill; **John Purcell**, CEO, Unfold Bio; **Megan Thomas**, Director of Marketing & Communications, Pairwise

October

Dr. Savithramma Dinesh-Kumar, Professor, Dept of Plant Biology, College of Biological Sciences, Genome Center, UC Davis
“Forgoing the GMO footprint: First steps to using viruses for gene editing in plants”

November

PANEL
“Focus on cannabis and hemp” featuring **Gail Taylor**, Professor, Chair of the Plant Sciences Dept, UC Davis; **Cindy Kiel**, Executive Associate Vice Chancellor, Office of Research, UC Davis; **Cameron Carter**, Distinguished Professor of Psychiatry and Psychology, Co-Director of the UC Davis Cannabis and Hemp Research Center; **Li Tian**, Associate Professor, Co-Director of the UC Davis Cannabis and Hemp Research Center; **Charlie Brummer**, Professor, Director of the Plant Breeding Center at UC Davis; **Dan Putnam**, Extension Agronomist and Forage Specialist, UC Davis; **Don Land**, Professor, Department of Chemistry, UC Davis; **George Hodgins**, Founder & CEO, Biopharmaceutical Research Company; **John McFerson**, VP of Breeding, Phylos Bioscience

December

Dr. Daniel Sumner, Distinguished Professor, Dept. of Agricultural and Resource Economics, UC Davis, Director, California Agricultural Issues Center – “The long-term future of California agriculture”; plus a Panel- “Newest research related to processing tomatoes and tomato processing” featuring **Amelie Gaudin**, Assistant Professor, Dept. of Plant Sciences, UC Davis; **Brenna Aegerter**, Cooperative Extension Farm Advisor, San Joaquin County, UC ANR; **Cassandra Swett**, Assistant Cooperative Extension Specialist, Dept. of Plant Pathology, UC Davis; **Chris Simmons**, Associate Professor, Dept. of Food Science and Technology, UC Davis; **Christian Nansen**, Associate Professor, Insect Ecology, IPM and Remote Sensing, UC Davis; **Daniel Geisseler**, Assistant Cooperative Extension Specialist, Land, Air and Water Resources, UC Davis; **Diane Beckles**, Associate Professor, Dept. of Plant Sciences, UC Davis; **Gitta Coaker**, Professor, Dept. of Plant Pathology, UC Davis; **Irwin Donis-Gonzalez**, Cooperative Extension Specialist, Dept. of Biological and Agricultural Engineering, UC Davis; **Luca Comai**, Professor, Genome Center, Department of Plant Biology, College of Biological Sciences, UC Davis; **Nitin Nitin**, Professor, Dept. of Food Science and Technology, UC Davis; **Steve Fennimore**, Cooperative Extension Weed Specialist, UC Davis; **Thomas Turini**, Vegetable Crops Farm Advisor, UC Cooperative Extension, Fresno County, UC ANR

2021

January

Dr. Philipp Zerbe, Associate Professor, Department of Plant Biology, College of Biological Sciences, UC Davis – “Identification of genes and metabolic pathways underlying crop stress resistance, plant-microbe interactions and flavor using functional genomics and biochemical approaches.”

5th INNOVATORS SHOWCASE at UC Davis featuring startups and innovative companies in seed, ag, agbiotech, microbiome, and food & health

February

PANEL

“Focus on microbiome and microbial research relevant to the seed, ag, agbiotech and food industry” featuring **Jonathan Eisen**, Professor, Unit Director, UC Davis Microbiome Special Research Program, Dept. of Evolution and Ecology, Dept. of Medical Microbiology & Immunology, Genome Center, Center for Population Biology; **Dorota Kawa**, Postdoctoral Scholar, Department of Plant Biology, Genome Center, UC Davis; **Douglas Cook**, Professor, Department of Plant Pathology, Director, Feed the Future Innovation Lab on Climate Resilient Chickpea, UC Davis; **Venkatesan Sundaresan**, Distinguished Professor, Department of Plant Biology, Department of Plant Sciences, UC Davis; **Joanne Emerson**, Assistant Professor, Department of Plant Pathology, UC Davis; **Magalie Guilhabert**, Head of Microbial Research Technologies, Bayer Biologicals; **Tom Williams**, Director of Microbiology, BioConsortia; **Brittany Pierce**, Group Leader, Microbiology Marrone Bio Innovations; **Laura Vann**, Genomics & Bioinformatics Scientist, Novozymes

March

Dr. Alison Marklein,

Climate & Agriculture Scientist, UC Riverside, “Projected temperature increases may require shifts in the growing season of cool-season crops and the growing locations of warm-season crops”

April

PANEL

“Her Startup: Encounters with women entrepreneurs who launched their own companies in ag & food, from seed to health” featuring **Lisa McDaniel**, Head of Global Outreach & Engagement, Vegetables R&D, Bayer Crop Science; **Kathryn Cook**, Co-Founder & CEO, NuCicer; **Fatma Kaplan**, Founder & CEO, Pheronym; **Ai Oikawa**, Founder & CEO/CSO, Afingen; **Hanne Sivertsen**, Founder, Sense of Taste; **Shely Aronov**, Founder & CEO, InnerPlant; **Holly Ganz**, Co-Founder & Chief Science Officer, AnimalBiome; **Abigail Stack**, Chief Technology Officer, Sentinel

May

PANEL

“Focus on artificial intelligence technology relevant to the seed, ag, agbiotech and food industry” featuring **Thomas Strohmer**, Professor, Director, Center for Data Science and Artificial Intelligence Research (CeDAR); **Ilias Tagkopoulos**, Professor Computer Science, Genome Center, Director & PI, AI Institute for Food Systems; **Nitin Nitin**, Professor, Food Science and Technology, Biological and Agricultural Engineering; **Aaron Smith**, Professor, Agricultural and Resource Economics; **Mason Earles**, Assistant Professor, Assistant Agricultural Engineer, Biological and Agricultural Engineering, Viticulture and Enology; **Pauline Canteneur**, Business Strategist, FarmWise; **Adam Greenberg**, CEO, iUNU; **Maurice Pitesky**, Co-Founder & CEO, Agrinerds; **David Sypnieski**, Founder & CEO, Athena Intelligence

September

Dr. Siobhan Brady, Professor, Department of Plant Biology, College of Biological Sciences, Genome Center, UC Davis – “Root Cell Type Development, Evolution and its Integration with the Environment”

October

Patty Buskirk, Managing Partner, Seeds by Design and Terra Organics

This event is part of Seed Central's series of events featuring women in our industry.

Previous events included:

Her Startup - Encounters with women entrepreneurs who launched their own companies in ag & food, from seed to health (April 2021)

The 'Job Panorama' in a seed company (April 2019)

Seed & agbiotech professionals with atypical backgrounds (March 2018)

Women in biotech (March 2017)

The seed industry is a great place for women to work - and for men too (January 2016)

November

Dr. Bhimanagouda 'Bhimu' Patil, University Regents Professor Texas A&M University, College of Agriculture and Life Sciences, Department of Food Science and Technology

"Breeding and consumption of specialty melons"

December

PANEL

“Focus on digital & AI technologies for agriculture” featuring **Aaron Smith**, DeLoach Professor of Agricultural Economics, UC Davis; **Brian Bailey**, Assistant Professor, Department of Plant Sciences, UC Davis; **Christine Diepenbrock**, Assistant Professor, Department of Plant Sciences, UC Davis; **Yufang Jin**, Professor of Remote Sensing and Ecosystem Change & Environmental Scientist in the AES, UC Davis; **Christopher Wong**, Postdoctoral Scholar, representing **Troy Magney**, Assistant Professor, Plant and Environmental Informatics Laboratory, UC Davis; **Grey Monroe**, Assistant Professor of Climate Adaptation with emphasis on Plant Genomics, Department of Plant Sciences, UC Davis; **Hamid Jafarbiglu**, PhD Student, representing Ali Pourreza, Director, Digital Agriculture Laboratory / Assistant CE Specialist, Biological and Agricultural Engineering, UC Davis; **Xin Liu**, Professor in Computer Science, UC Davis

2022

January

Kent Bradford

Distinguished Professor
Emeritus Founder, Seed
Biotechnology Center
Co-Founder, Seed Central
UC Davis

"Understanding the
behavior of seed (and
cell) populations"
Following up on this
presentation, Kent
Bradford will present and
discuss his vision for new
developments in seed
science and technology
at a Seminar Series,
offered to Seed Central
Premium members.

...

**6TH INNOVATORS
SHOWCASE**

UC Davis
Online edition 2022
Featuring startups and
innovative companies in
ag and food, from seed
to health

February

Luca Comai

Professor
Manager, TILLING Core
UC Davis Genome Center
"Breeding plants with
genes from 1 parent -
Advance could shorten
times for crop breeding"

March

John Palmer

Executive Director
Emeritus, California Crop
Improvement Association
and UCD Foundation
Seed Program
John retired at the end
of 2021, after a 40-
year career in the seed
industry. He is widely
known both for his
industry expertise and for
his eloquence and wit, so
we asked him to speak on
a topic that will allow the
audience to experience
both: "What are the 10
most important things you
have learned during your
long and distinguished
career in the seed
industry, and what are the
10 least important ones?"

April

PANEL

FOCUS on indoor and
vertical agriculture

Featuring:

Gail Taylor, Prof. Chair of
the Plant Sciences Dept.
UC Davis

Heiner Lieth, Prof. and
Extension Specialist,
Plant Sciences Dept. UC
Davis

MD Shaamin Ahamed,
Assistant Prof.
Department of Biological
and Agricultural

Engineering UC Davis
Max Vo, Plant Sciences
Researcher at UC Davis

Swasti Reddy, Product
Development Manager
David Nothmann, COO

Unfold Bio

May

6TH INNOVATORS SHOWCASE

In-person edition 2022
Featuring startups and
innovative companies
in ag and food, from seed to
health

...

PANEL

Discussion on
upcoming scientific
and technological
developments around
plant breeding and food
science being increasingly
tailored towards
'personalized' health.

...

**Seed Central Webinar Series
with Kent Bradford**

1st installment:
Understanding populations:
implications for breeding vs.
seed biology/technology

September

Bárbara Blanco-Ulate

Associate Professor
Dept. of Plant Sciences
UC Davis

"Improving crop quality and reducing
postharvest losses through fruit
biology research"

**Seed Central Webinar Series with
Kent Bradford**

2nd installment:

"Going deep: how populations
underlie biological mechanisms"

October

Neelima Sinha

Distinguished Professor
UC Davis College of Biology
"A developmental biologist's
perspective on crop
improvement"

**Seed Central hosts
the California Seed
Association's Fall Student
Tour for lunch and a
networking career fair
Hartnell College, Salinas,
California**

With students from UC
Davis, Cal-Poly, California
State University Chico /
Fresno / Monterey Bay, and
Hartnell College

November

**FOCUS on digital & AI technologies for
agriculture and food in collaboration with:**

- CeDAR, Center for Data Science and
Artificial Intelligence Research
- AI Institute for Next Generation Food
Systems

**Jim Pantaleo, Yufang Jin, Martin Kenney,
Troy Magney, Aurelie Bak, Martin Ruebelt,
Rakesh Kumar.**

**Seed Central Webinar Series with Kent
Bradford 3rd installment:**

Going big: populations in evolution,
adaptation and selection

December

**FOCUS on new genetic technologies
and their potential application to
processing tomato**

In collaboration with the
California Tomato Research Institute.
Video recording of the 6 presentations.
Audio recording of the panel discussion.

**Martha Mutschler-Chu, Anna
Whitfield, Siobhan Brady, Cassandra
Swett, Jiaqi Zhoi, Dave Tseng, Luca
Comai**

Imtiyaz Khanday

Director of Research
Seed Biotechnology Center UC Davis
"Creating seeds for the future: clonal,
resilient, and high vigor"



UC DAVIS

Plant Breeding Center

Director, **Charlie Brummer**; Associate Director, **Allen Van Deynze**; Program Representative, **Amanda Saichaie**

The Plant Breeding Center continued with our virtual plant breeding activities in 2021. We collaborated with Seed Central to bring several professional development opportunities for students across the country. Our programming included a workshop on the legal matters encountered in the seed industry, job panoramas, and a Q&A on interviewing skills with a hiring manager.

The PBC held successful retreats in 2021 and 2022. The retreats included scientists from the USDA, UC Riverside, UC Berkeley, and Cal Poly Pomona in addition to UC Davis. In 2021 we hosted a virtual event at which Steve Knapp gave a keynote presentation on the UC Davis strawberry breeding program. For the second year in a row, UC Davis graduate students led a virtual event that pairs networking and plant breeding trivia. The 2022 retreat (delayed to March 2023) was held in-person for the first time in two years. Attendees gathered at UC Davis to present posters, and Paul Gepts gave the keynote on

the bean program. Once again, it was a great way to facilitate new connections across California.

In 2021, the PBC received funding from USDA-NIFA for a second cohort of National Needs Fellows. The program aims to recruit students from underrepresented groups into a graduate program in plant sciences. In 2022, the Department of Plant Sciences, in collaboration with the Plant Breeding Center, was also awarded a Multi-Cultural Scholars Program grant to support incoming undergraduate and transfer students entering the major of Plant Sciences. These funding opportunities are part of the PBC's initiative to recruit diverse scholars to UC Davis, creating a pipeline from high schools to graduate programs in crop improvement. We also submitted a proposal to finalize a Graduate Academic Unit Certificate in plant breeding, and hope to receive approval in the upcoming academic year. The list of necessary courses can be found on our website.

The university's Germplasm and Cultivar Release Committee, chaired by PBC director Charlie Brummer, approved the release of UC Tehama Barley by Allison Krill-Brown. The committee also approved the UC-Westside Pistachio release from Craig Kallsen and Dan Parfitt.

In the media, both Charlie Brummer and Allen Van Deynze were highlighted in stories by Ag Alert. The digital magazine reported on their research into downy mildew in leafy greens, and on Allen's mechanically harvested peppers.

The Student Collaborative for Organic Plant Breeding Education (SCOPE) hosted a small grains field day in collaboration with the California Wheat Commission. The student-led breeding program welcomed two new grant projects in celtuce and sweet potato. The tomato team ran its first replicated trial of tomato hybrids at both UC Davis and Cal Poly Pomona. The new zinnia breeding program ran a second round of vase life testing, with some cut flowers lasting up to 20 days. Looking to the future, the pepper breeding team are preparing their first variety releases scheduled for next year.

As the UC Davis community returns to campus for the 2023 academic year, plant breeding at UC Davis is thriving. We look forward to a new year of educational and professional development that embraces the benefits of both virtual and in-person events. The PBC's website can be found at www.plantbreeding.ucdavis.edu.



The Collaboration for Plant Pathogen Strain Identification (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 has been based at SBC since 2015 with **Phyllis Himmel** as the director. CPPSI priorities are to recruit members, develop new sets of plant pathogen strain differentiating Reference Materials, and collaborate with similar organizations to enable the consistent identification and 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 and run comparative ring tests, write and review articles and white papers, and address any issues that come up in our work.

REFERENCE MATERIAL DEVELOPMENT AND DEPLOYMENT

Reference Materials for watermelon *Fusarium* wilt, tomato ToMV, spinach Downy mildew, melon *Fusarium* wilt, pepper Bacterial spot, lettuce Downy mildew, tomato TSWV, and pepper TSWV are currently available via the CPPSI website. We anticipate a 2023 launch of Reference Materials for the pepper Tobamoviruses, tomato *Fusarium* wilt, and tomato Root knot nematode.

The table below shows the status of CPPSI Reference Material development and deployment pipeline from the beginning of CPPSI through today. This is a summary of the full tracking spreadsheet that lists both completed sets of Reference Materials and the details of

what remains to be done for those sets still in development. Reference Materials are grouped into rounds that can be identified by the year they are approved by the CPPSI Advisory Council. Representatives of seed company sponsors of CPPSI make up the Advisory Council members.

Eight disease systems have been deployed as Reference Materials, three are ready to deploy and ten are in various stages of development. The CPPSI development pipeline is primed to release 2 - 3 new sets of reference materials each year while continuing to initiate work on new disease systems.

Table 1. Reference Materials development status

	Host	Pathogen	Approval date	Current Activities	Expected deployment
Round 1	melon	Fusarium wilt	2007	Complete	Deployed 2010
	pepper	Bacterial spot	2007	Complete	Deployed 2010
	spinach	Downy mildew	2007	Complete	Deployed 2010
	tomato	ToMV	2007	Complete	Deployed 2010
Round 2	lettuce	DM	2016	Complete	Deployed 2020
	pepper	TSWV	2016	Complete	Deployed 2019
	tomato	TSWV	2016	Complete	Deployed 2019
	watermelon	Fusarium wilt	2016	Complete	Deployed 2021
Round 3	tomato	RKN	2017	Complete, not deposited	2023*
	tomato	Fusarium wilt	2017	Complete, not deposited	2023*
	melon	Powdery mildew	2017	Final ring test completed	2024
Round 4	pepper	PVY	2018	Host final verification	2024
	pepper	PepMoV	2018	Host final verification	2024
	pepper	Tobamoviruses	2018	Complete, not deposited	2023*
	tomato	Verticillium wilt	2018	White paper	2023
Round 5	tomato	Spot	2019	Host increase ready in June 2023, white paper	2024
	tomato	Speck	2019	Host increase ready in June 2023, white paper	2024
	pepper	Phytophthora crown and root rot	2019	Final ring test under way, white paper	2024
Round 6	cucumber and watermelon	Anthraxnose	2021	Differentiating hosts identified, being increased, reference strains cultured	2025
	watermelon	Powdery mildew	2021	Differentiating hosts identified, need to be increased, collecting reference races	2025
	pepper	CMV	2021	Differentiating hosts being increased, reference strains cultured in plants	2025
Round 7	sunflower	Downy mildew	2023	Proposals to be discussed	2026
	melon	CMV	2023		
	cucumber	CMV	2023		

* delayed to 2023 by recent personnel turnover at USDA National Plant Germplasm Center - all permits must be renewed before accepting additional CPPSI Reference Material deposits.

COMPARATIVE TESTING OF REFERENCE MATERIALS

In collaboration with members of the International Seed Federation Expert Group Disease Resistant Terminology (ISF EGDRT), CPPSI working group members have completed comparative ring tests for three disease systems: watermelon *Fusarium oxysporum* f. sp. *niveum* (Fon), pepper *Phytophthora capsici* (Pc) and melon *Podosphaera xanthii* (Px). Each set of ring tests can take up to 12 months to complete. Results offer a broad scope of important feedback on each tested disease system.

Watermelon Fon causes a wilt in mature plants (Fig. 1) and kills seedlings. The brown vascular discoloration that develops at the plant crown is a key diagnostic symptom (Fig. 2). The ring test was organized between US, Asia and EU partners in 2021 – 2022 evaluated lab-to-lab consistency in testing and host responses. Results confirmed expected susceptible and resistant host responses and revealed the variable resistant response of the host, Calhoun Grey, to Fon race 1. A new source of Calhoun Grey with a known 100% resistant response to Fon race 1 was acquired to replace this host.



Fig. 1. *Fusarium* wilt in watermelon (Purdue)



Fig. 2. Vascular discoloration (Purdue)

Pepper Pc - Results from three rounds of tests identified reference isolates and hosts that could facilitate differentiation of standard from aggressive Pc isolates. In addition, two tested lines tested resistant to aggressive Pc isolates in each round of testing. The disease causes a crown and root rot in pepper (Fig. 3) that wilts and kills plants. The same symptoms can be induced in greenhouse disease tests (Fig. 4). We defined standard isolates as those controlled by the level of resistance found in the pepper varieties Paladin and Aristotle, and aggressive isolates as those that overcame the resistance found in Paladin and Aristotle. These differentiating hosts and reference isolates are being prepared for release as CPPSI reference materials in 2024.



Fig. 3. Symptoms of *P. capsici* in field pepper



Fig. 4. Symptoms of *P. capsici* in pepper greenhouse test

Melon Px - was organized by GEVES-MATREF to identify a set of differentiating hosts to identify commercially relevant races of *P. xanthii*. The last of three comparative ring tests were completed in 2022. A set of 11 differentiating hosts were identified that could potentially differentiate 10 races of Px. A subset of hosts was able to consistently differentiate and identify the commercially relevant races of Px: 1, Px: 2 US and EU, Px: 3.5 (Uber in CA) and Px: 5 (Fig. 5). These hosts and races can now be advanced as CPPSI Reference Materials. Differentiating hosts and reference races will be available from CPPSI and GEVES-MATREF in 2024.

These are important projects that ensure the differentiating hosts and reference pathogen races or strains created and revised by CPPSI and the ISF EGDRT are equivalent and promote consistent strain and race naming on a global scale.

CPPSI now collaborates with the Asia Pacific Seed Association (APSA) Disease Resistance Terminology Working Group to harmonize disease resistance terminology, use of pathogen codes, and claims of resistance against diseases that occur in this region. We meet quarterly by conference call led by APSA leadership. After several in-depth discussions of disease and crop priorities, the group is organizing the first and second comparative ring tests for this region: bittergourd *Podosphaera xanthii* and watermelon *Fusarium oxysporum* f. sp. *niveum*.

CPPSI members also collaborate with the ISF EGDRT to develop and update pathogen abbreviation lists and tables of differential host posted on the ISF website. The focus is on vegetable and flower disease and insect pest systems against which commercial claims of disease resistance are made on a global scale.

ISOLATE	Px: 1 Matref	Px: 2 Matref	Px: 5 Matref	Uber race
Origins	Matref	Matref	Matref	Yolo County
Vedrantais	S	S	S	S
PMR45	S	S	S	S
Edisto47	R	R	S	S
PMR5	R	R	R	S
Durango	R	R	IR	IR
Arum	R	R	R	R
SVI105	R	R	R	R

Fig 5. Results from watermelon Fon Test. S=susceptible, R=Resistant and IR=incomplete resistance.

THE CPPSI WEBSITE AND OPERATIONS ANALYTICS

The CPPSI website, cppsi.ucdavis.edu, facilitates the distribution of Reference Materials via the network of USDA National Germplasm Centers. The website also provides CPPSI Services to order sets of Reference Materials for you. CPPSI Services are free to CPPSI members and available to non-members for a nominal fee. In 2022, we tracked 1,700 visitors to the CPPSI website. The table below lists the yearly number of visitors to the CPPSI website. Each year, returning visitors make up about 10 - 20% of all visitors. The origin of visitors to the CPPSI site remains global.

Host set distribution is global with approximately 60% of requests coming from academia and 40% from industry – with occasional requests coming from private individuals. Approximately 100 host sets are delivered annually. Since 2010, a total of 1204 sets were distributed by the end of 2022.



RESEARCH

GENETICS, GENOMICS AND BREEDING

AFRICAN ORPHAN CROPS CONSORTIUM

In 2020-2022, the African Orphan Crops Consortium (Allen Van Deynze, Scientific Director) was able to continue working on several projects with support from its partners from around the world despite restrictions related to Covid-19. The main challenge has been with collecting tissue for DNA and RNA extraction from species across Africa. Nevertheless, with collaborators from University of Georgia (led by Jeff Bennetzen and Jason Wallace), University of Ghent and University of Pretoria (led by Yves Van de Peer) a high-quality genome of white fonio (*Digitaria exilis*) was completed, revealing key genes to improve production of this ancient grain, especially important in West Africa. Similarly, Iago Hale (University of New Hampshire) led a program to characterize the genome of Shea (*Vitellaria paradoxa*) with Yves Van de Peer's group, University of Ghana and the World Agroforestry Center, also revealing key genes for quality. Work led by Daniel Rokhsar and Jessica Lyons (UC Berkeley), Prasad Hendre, Ramni Jamnadass, Alice Muchugi (World Agroforestry Center)

and Ranjana Bhattacharjee (International Institute of Tropical Agriculture) on the water yam (*Dioscorea alata*) genome revealed its domestication pathway. Work led by Katherine Denby (University of York) and Yves Van de Peer's group resulted in a chromosomal level genome of vegetable amaranth (*Amaranthus cruentus*). Finally, an in-depth analysis of Moringa (*Moringa oleifera*) led by Yves Van de Peer, the SBC and Lorenzo Carretero-Paulet (University of Almeria, Spain) revealed that genes important in glucosinolates and secondary metabolites are collocated and amplified in its DNA. Each of these projects have been published and the genomes are available at <https://bioinformatics.psb.ugent.be/orcae/aocc/>. The above work leveraged the AOCC resources including the UC Davis Genome Center. It is already being used to define genetic diversity and serves as a basis for genome-assisted breeding in these African crops by graduates of the African Plant Breeding Academy.



CARROT

THE GENETICS OF BOLTING IN CARROT

In 2020 and 2021, the SBC completed work with Phil Simon (USDA/ARS, Madison, WI) on a multi-year grant to discover and characterize resistance to bolting as well as other quality and production traits. In the 4th year of this 5-year project, Theresa Hill, Armando Garcia-Llanos, Shiyu Chen and Allen Van Deynze now have 4 years of data on bolting of 675 diverse carrot lines from 5 locations including Hancock, WI, El Centro, Riverside and Coachella, CA in fall and spring plantings. Environments were clearly separated into 3 zones between spring and fall-planted environments with Riverside spring-planted carrots having unique bolting patterns. Lines that bolted readily or not at all in all environments were selected to develop targeted populations to further dissect this trait. Additional data on pooled samples were sequenced and analyzed. Unfortunately, the SBC was not able to extend its K-12 outreach program with the UC Davis Student Farm in 2020 due to Covid. Collaborating institutions include USDA/ARS, University of Wisconsin, UC Riverside, University of Washington and Cornell University. This program was funded by USDA Specialty Crops Research Initiative. A second SCRI grant was received in late 2022 to expand and implement genomic resources in breeding populations.

CELERY

A BASE FOR GENOME-ASSISTED BREEDING IN CELERY

The SBC (Van Deynze and Armando Garcia-Llanos) is working with Lynn Epstein (UC Davis) to sequence the genome of a founding variety, Challenger, that has resistance to Fusarium race 2. Due to its complex genome, we are taking an integrated

approach using Oxford Nanopore, Pacific Biosciences HIFI, as well as genetic and transcriptome mapping to assemble and annotate the genome. Sequencing is being done at the UC Davis Genome Center. A chromosome level sequence is now being annotated by Chaehee Lee (postdoc) and Grey Monroe from UC Davis. This work is funded by Bejo BV, BASF Vegetable Seeds and the California Celery Board.

CHICORY AND ENDIVE

RAISING THE BAR FOR LEAFY GREENS

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), the SBC has assembled and annotated the endive genome. We are now annotating the assembled chicory genome 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 resources in collaboration with Rijk Zwaan BV.

MAIZE

NITROGEN FIXATION IN MAIZE

To continue published work (Van Deynze et al. 2018. PLOS Biology) where we described a landrace of maize that associates with bacteria to fix 50% of its nitrogen from the air, the SBC partnered with Alan Bennett and Bart Weimer (UC Davis) to decipher the inheritance of nitrogen fixation in maize to understand the bacteria involved in N-fixation and to understand the interactions and mechanisms involved in N-fixation in maize. In 2021 and 2022, we established trials and showed that we can repeat in Hawaii the phenotypes in populations derived from select landraces, a very

different environment than the highlands of Oaxaca, Mexico. We are also analyzing the microbiomes associated with those nitrogen-fixing lines. The work was carried out by Chandler Levinson, Gizaw Wolde (postdocs), Angel Avalos (PhD, graduate student) and Lindsay Rodgers (undergraduate). It is funded by the Foundation for Food and Agricultural Research and Benson Hill.

MELON

RAPID PHENOTYPING FOR QUALITY

Allen Van Deynze, Kent Bradford and Dario Cantu (UC Davis) worked with HM.Clause to develop high-throughput methods for phenotyping melon quality. Postdoctoral researcher Macarena Farcuh (now faculty at University of Maryland) has compared the results from sensory analyses with flavor and aroma on field-grown melons. As expected, there was an increase in ethylene with storage time in all melons, but at different rates. Aldehydes were associated with a green grassy aroma in long-shelf life melons while esters were correlated with fruity flavors and aromas, indicating that targeted metabolic profiles can be selected to reflect flavor and aroma in breeding (see Farcuh et al. 2020). This research was funded by HM.Clause.

PEPPER

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. A systems approach that combines specific varieties, types of harvesters and crop management is 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 pedicel, to ensure uniform

ripening, and to adapt plant architecture to mechanical harvesting. The SBC has 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 and CA using an Etgar Inc harvester. The results show that the force to destem is directly correlated with amenability to mechanical harvesting. In 2020-2022, we confirmed results from 2018 and 2019 and are advancing populations and lines to combine traits. The first green New Mexico Type variety, Odyssey, with improved harvestability is being released by New Mexico State University. The destemming trait is now being introgressed in those materials. Genetic mapping of the trait indicates a unique pathway is involved in controlling destemming. Theresa Hill, Shiyu Chen and Sirisupa Sripolcharoen in collaboration with Stephanie Walker, Bradley Tonnessen and Franchesca Ortega (New Mexico State University) worked on this program with support from USDA/NIFA, and a UC Davis Science Translation and Innovative Research grant. A second USDA/NIFA grant was obtained beginning in 2021.

STRUCTURAL VARIANTS - THE OTHER SOURCE OF VARIATION

The SBC is working with Byoung-Cheorl Kang (Seoul National University, Korea), Ilan Paran (The Volcani Center, Israel) in a consortium with NRGene to define structural variants in Capsicum. Eleven pepper varieties have been sequenced de novo and structural variants (SVs) associated with genes are being mined. Structural variants including copy number variants, large deletions/insertions, inversions, translocations and presence/absence variants have been shown to be the causative differences in alleles for important phenotypes such as plant architecture, fruit traits and yield in crops like tomato. They are likely to be important in pepper breeding. A manuscript has been published in Plant Genome with data available on the Solanaceae Genomics Network (SGN).

PROTECTION TO A RESISTANCE-BREAKING STRAIN OF TOMATO SPOTTED WILT VIRUS IN PEPPER

The Tsw gene in pepper has been effective for decades. In 2018, resistance-breaking TSWV strains (RB-TSWV) to the Tsw gene were identified in Yolo, Merced and Fresno counties by Robert Gilbertson (UC Davis). Their prevalence is increasing annually, now to coastal areas. In collaboration with the Gilbertson lab, we screened and identified several potential sources of resistance. The SBC is introgressing and characterizing the inheritance of a single source of resistance in blocky, New Mexico type and jalapeno peppers. By 2022, we have advanced selections to Backcross 2 (BC₂) and are evaluating segregation in F_{2:3} populations. This trait is being combined with mechanical harvest traits. Allen Van Deynze, Armando Garcia-Llanos, Theresa Hill, Maria Rojas and Robert Gilbertson are leading the project. Funding is from the California Block Specialty Crops Grant program and USDA/NIFA.

YIELD UNDER WATER AND HEAT STRESS

The SBC has initiated a breeding program to develop peppers that yield under water deficit and heat stress. In 2022, 25 populations derived from backcrosses between 15 landraces collected in arid/semi-arid regions and elite jalapeño lines were planted late to invoke heat stress and screened in the field under water deficit. Twelve promising populations are being advanced for further breeding, and screening and characterization. Theresa Hill and Gen-ha Park (Phd Student) are conducting the work.

GENE EDITING IN PEPPERS

Gene editing is being developed in several crops, proving to be an effective way to characterize the genetic basis for traits and create new phenotypes and varieties. It is an essential breeding tool. Pepper is recalcitrant to traditional *Agrobacterium* transformation. To circumvent this, the SBC has been systematically testing the use of carbon nanotubes to deliver and express CRISPR/Cas9 to edit targeted genes in pepper. Thus far we have been able to show transient gene expression of GFP and/or Cas9 in meristems, embryos, axillary buds and pollen. We are in the process of testing gene editing. This work is a collaboration with Markita Landry (UC Berkeley). Theresa Hill and Trent Sripolcharoen lead this work. It is funded by Rijk Zwaan BV and the SBC.

POTATOES

APOMIXIS IN CROP PLANTS

Previous postdoctoral work by Dr. Imtiyaz Khanday has led to the introduction of clonal asexual seed formation or synthetic apomixis in rice. This breakthrough in agricultural biotechnology will enable the fixation of vigor in hybrid crops, make hybrid seeds cost-effective for farmers, make the breeding programs cheaper and speed up plant breeding. Starting his lab at the SBC in July 2021, Dr. Khanday is working to further develop clonal seed technology for its field applications. His lab is also pursuing engineering it in vegetatively-propagated crops like potatoes, with the benefits to allow propagation from clonal botanical seed that ensures disease-free propagation and prevents the loss of produce resulting from using tubers as propagules. This research work at the SBC is supported by the Innovative Genomics Institute (IGI), UC Berkeley, through the Shurl and Kay Curci Foundation Faculty Scholars program.

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 and reduced uptake of cadmium in baby leaf spinach. Allison Krill-Brown is the plant breeder implementing the program in collaboration with Steve Klosterman, Amy Achieta, Kelley Clark and Shyam Kandel (USDA/ARS) from Salinas. In 2020, four organic and conventional field trials were conducted in Salinas, Davis and El Centro to evaluate disease resistance, leaf quality and yield in trials with up to 400 entries from 2 to 39 populations. Similarly, in 2021, over 600 families were evaluated in one organic, 2 conventional and 1 low nitrogen trial. The program continues to refine technologies to screen populations year around against freshly-collected downy mildew isolates in growth chambers and with leaf-detachment assays. Genotyping on a whole genome basis and also for specific markers for monoecy and R-genes are being implemented. Similarly, lines with reduced uptake of cadmium were verified in replicated trials and bi-parental populations are being used to genetically map loci for this trait. Samantha Hilborn, Danyelle Forte, Oon-ha Shin and Sheriff Seedy-Phaal (graduate students), Arsenio Ndeve (Postdoc) and Daniel Pap support the program. This program is funded by the California Leafy Greens Board with in-kind support by USDA/ARS and a CDFA 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 nitrogen use efficiency. With increasing costs and environmental pressure, NUE is becoming an important trait for spinach. Currently, growers use 150-200 kg/ha of nitrogen to grow baby spinach to meet consumer and grower demands for rapid growth and a dark green product in this 3-4 week crop. Oon-ha Shin (PhD student) is working with Allen Van Deynze, Charlie Brummer and Allison Krill-Brown to screen 448 lines of spinach in the field for NUE, as well as breeding populations segregating for downy mildew resistance. In 2020-2022, accessions were screened in low-nitrogen trials in Davis including 136 breeding lines. The trial was also scanned with hyperspectral imaging to develop rapid screening for NUE traits using drones or mounted cameras. 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 Multi-State program.

DOWNY MILDEW OF SPINACH

To develop rapid assays for growers and scientists and to better understand the interactions between downy mildew and spinach, the spinach group worked with Steve Klosterman, Amy Achieta and Kelley Clark (USDA/ARS) to develop a rapid cost-effective assay to detect presence of downy mildew in fields. The assay was demonstrated in a webinar and can detect presence of the pathogen prior to detecting symptoms. A publication was submitted for review and accepted in 2022 (Clark et al. 2022 in Plant Disease). In an effort to further understand pathogenicity and eventually develop isolate-specific assays, the group has sequenced an isolate collected in California. The first chromosomal assembly of the downy mildew pathogen (and Oomycetes) was achieved, revealing important distribution and annotation of genes for specificity

and pathogenicity of this pathogen. Kyle Fletcher and Richard Micheltore (UC Davis Genome Center) conducted the genomic analyses (Fletcher et al. 2022 Molecular Plant-microbe interactions) with support by Jim Corell (University of Arkansas). This work was funded by the California Spinach Committee and The Novozymes Inc. Endowed Chair in Genomics.

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). 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. To demonstrate the Dry Chain in practice, we collaborated with Denise Costich, head of germplasm preservation and her colleagues at CIMMYT in Mexico, in a community-based maize seed preservation program in Guatemala (see Guzzon et al. 2020 in Publications).

Local seed repositories encouraged local farmers to preserve their planting seeds for the following season using Dry Chain methods, i.e., drying with desiccant beads and storing in hermetic containers. After six months, dramatic differences in seed germination and viability were

observed, with the seeds stored under Dry Chain conditions retaining their vigor and viability, while seeds stored in cloth mesh bags (local practice) lost up to 30% in emergence capacity. In some cases, the current practice in the repositories (storage in hermetic containers without drying) performed even worse than in the porous bags. This illustrates the importance of initial drying of seeds, followed by hermetic storage in humid climates. With this “make it dry, keep it dry” combination, seeds can easily be stored from one season to the next without refrigeration.

In another study concerning the Dry Chain, collaborators in Hyderabad, India showed that desiccant drying, particularly using Drying Beads, extended the viability of mung bean seeds and prevented damage due to bruchid beetles during storage (see Sultana et al. 2021 in Publications). Seeds were dried to different moisture contents and stored in hermetic containers under ambient temperatures. Some containers with seeds were also inoculated with adult bruchids. While air-dried samples



suffered 30% damage or more, desiccant-dried seeds were undamaged and the introduced insects did not survive.

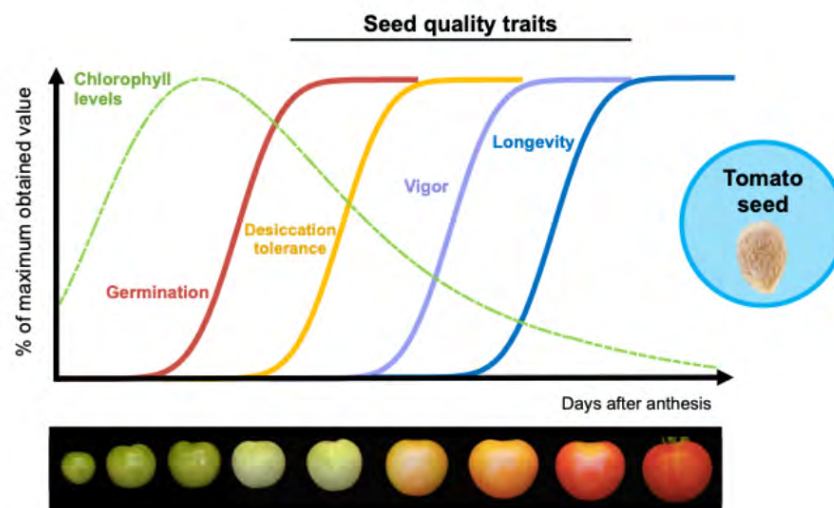
Another advantage of dry, hermetic storage is prevention of increases in fungal growth that can result in the accumulation of mycotoxins in stored grains, peanuts and other commodities. Fungi cannot grow when the equilibrium relative humidity is less than 70%, or approximately 13% moisture content for cereal grains (8% for peanuts). This prevents further growth of *Fusarium* and *Alternaria* species that produce toxins such as fumonisin and aflatoxin. In addition, waterproof storage containers would help prevent losses due to flooding and preserve food stocks for distribution in such disasters. In an opinion piece co-authored by plant scientists, nutritionists, medical doctors and public officials, implementation of the Dry Chain was urged as part of a global effort to reduce toxins in the food of many already undernourished people in tropical regions (see Dahal et al. 2020 in Publications).

SEED PHYSIOLOGY AND TECHNOLOGY

TOMATO SEED QUALITY IN RELATION TO FRUIT RIPENING AND TEMPERATURE DURING SEED MATURATION

Tomatoes are now primarily planted in the field or greenhouse as transplants, putting increasing demands on seed performance to deliver rapid and complete germination for transplant production. As the maternal environment during seed development can have major impacts on seed set as well as quality, and the majority of hybrid tomato seeds are produced under (at least partially) controllable conditions, we have undertaken a research program to identify genetic and physiological factors contributing to high seed quality. Kent Bradford with Co-PIs Roger Chetelat and Barbara Blanco-Ulate of UC Davis and Alfred Huo of the University of Florida have received a 3-year \$1.1 million grant (initiated in late 2020) from the Foundation for Food and Agriculture Research (FFAR) supported by contributions from multiple seed

companies. Roger Chetelat and Xiaoqiong Qin are identifying new loci associated with seed set and seed quality in a *Solanum sitiens* introgression line population. Barbara Blanco, Kent Bradford and Pedro Bello are investigating the development of seed quality and its relationship to fruit ripening and temperature. Alfred Huo is developing novel approaches for gene editing and the possibility of temporary delivery of regulatory molecules (such as microRNAs) to affect plant, fruit or seed development. Modern single-seed approaches (imaging, respiration, etc.) are being applied to assess seed quality in relation to these genetic, developmental and environmental factors (see below).



USING SEED IMAGING TO PREDICT GERMINATION PERFORMANCE AND PLANT BLINDNESS

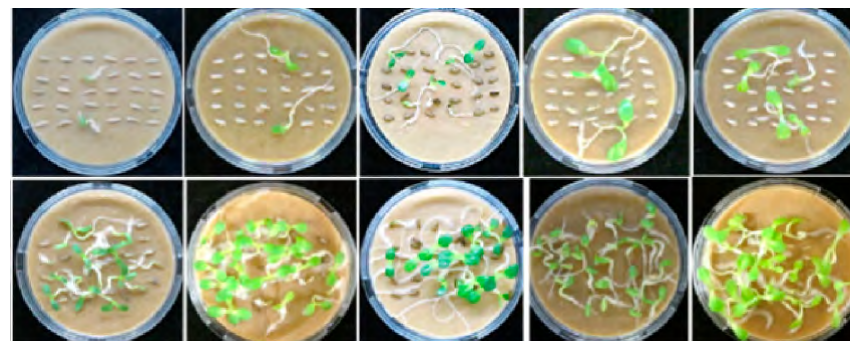
Digital imaging is being applied in many fields to quantify surface features and relate them to other useful properties. In seed conditioning, color sorting equipment is advancing rapidly, making it possible to use multiple wavelengths to sort seeds into different categories at high speed. In his MS Thesis (see Publications), Pedro Bello in the Bradford

Lab has now demonstrated that some quality characteristics of Brassica (kohlrabi) seeds can be detected using non-destructive spectral analysis methods. In particular, the sensitivity of individual seeds to exhibit blindness (failure of the apical meristem) in response to cold imbibition was significantly correlated with certain spectral features. He used the CF Mobile® instrument to measure chlorophyll content of individual seeds, an indicator of seed maturity. In addition, the VideometerLab® instrument was used to collect and analyze images of individual seeds in multiple wavelengths to detect specific microorganisms or physical variation or defects. With collaboration and support from several seed companies in the Western Regional Seed Physiology Research Group, Pedro imaged individual seeds by these methods and subsequently assessed their germination characteristics, including through single-seed respiration measurements using the Q2 instrument. Seed reflectance at certain wavelengths, particularly those associated with chlorophyll, were highly correlated to their respiration and germination performance and susceptibility to induction of blindness (see Bello and Bradford 2021 in Publications). This may enable sorting of seed lots to remove seeds of lower quality or higher susceptibility to blindness.



WATER-SOLUBLE NANOPARTICLES CAN IMPROVE LETTUCE SEED GERMINATION

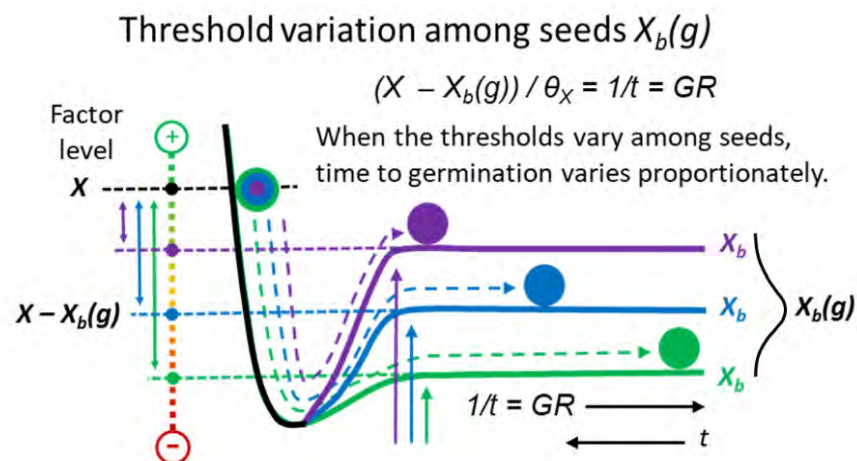
Carbon nanoparticles are being explored for their ability to carry biological molecules such as DNA or RNA into plant cells. To explore this area, Dr. Heqiang (Alfred) Huo and colleagues at the University of Florida (formerly a postdoc with K. Bradford in the SBC) tested the effects of such nanoparticles on the germination of lettuce seeds under salt stress conditions (see Baz et al. 2020 in Publications). The effects varied by variety, but in some cases nanoparticles markedly improved germination speed and percentage under moderate salinity stress (~150 mM NaCl) and warm temperatures (34°C). While the mechanism of these effects remains to be identified, they indicate that the particles are likely penetrating into the seeds, potentially allowing additional uses to be pursued.



APPLYING POPULATION-BASED THRESHOLD MODELS TO QUANTIFY AND IMPROVE SEED QUALITY

Population-based threshold models provide a quantitative approach to assessing seed quality in relation to temperature, water potential, storage longevity, hormones, priming and other factors. Kent Bradford and Pedro Bello have written a book chapter providing an extensive description of these models and how they can be used to measure and improve seed quality. The chapter covers the diversity of applications of these models that have been identified over the past 30+ years and

the insights gained into how seed behavior can be viewed as the result of systematic variation among individual seeds in their sensitivities to various genetic, physiological, developmental and environmental factors (see Bradford and Bello 2022 in Publications).

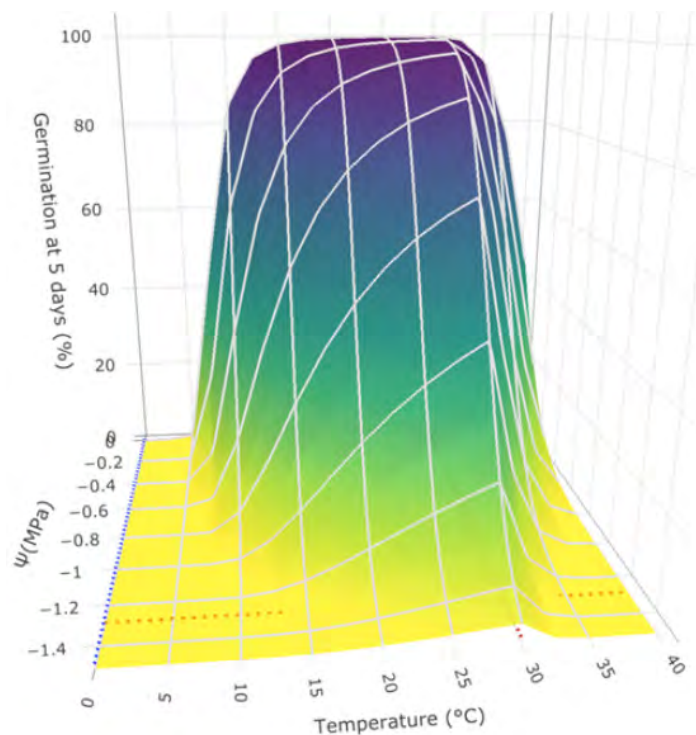


SEED GERMINATION MODELS DESCRIBE BEHAVIOR ACROSS SALINITY AND TEMPERATURE

The hydrotime and thermal time models can quantify seed responses to reduced water potential and across temperatures, respectively. These can also be combined into a hydrothermal time model that has been used to predict optimal conditions for seed priming, for example. Now, working with collaborators in Iran, this model has been extended to include the effects of salinity levels in a halothermal time model (see Bakhshandeh et al. 2020 in Publications). This allows pretesting of seeds for their sensitivity to salinity and prediction of the potential germination performance in saline soils and across all temperatures permitting germination.

HYDROTHERMAL SENSITIVITIES OF SEED POPULATIONS INDICATE DORMANCY STATES IN A DESERT ANNUAL PLANT COMMUNITY

In a plant community, there are continuous interactions between changing environmental conditions and the responses of seed populations to those conditions, particularly in a desert environment. Different annual species exhibit adaptive life cycles that depend upon taking germination opportunities that may occur (i.e., rainfall) while also assuring that some of the seeds remain dormant in case conditions subsequently change for the worse. As part of a long-term study of an annual plant community near Tucson, Arizona, we characterized the hydrothermal sensitivities of seed germination of 15 species and how these changed in response to dry after-ripening (see Liu et al. 2020 in Publications). Field emergence fractions and mean emergence dates over 25 years of observations were highly correlated with hydrothermal time parameters derived from the population-based threshold model. The hydrothermal limits for germination and their patterns following after-ripening varied widely among species. This should improve our ability to predict vegetation responses to environmental change and enable more mechanistic ecological modeling of plant populations and communities.



SEED DORMANCY AS A FACTOR IN ECOLOGICAL BET-HEDGING

Seed dormancy has evolved to increase the success of reproduction of angiosperms. Dormancy allows seeds to persist through periods when the environmental conditions are not conducive to successful seedling growth and to time their germination and emergence to coincide with conditions offering a higher probability of survival. The ability of species to adjust the variation in dormancy in their offspring in relation to the variability of the environment in which they are growing is known as “bet-hedging”. Kent Bradford was a coauthor of a review on “Ecological, (epi)genetic and physiological aspects of bet-hedging in angiosperms” that discussed this topic and the relationship of population-based models in understanding this aspect of seed ecology (see Gianella et al. 2021 in Publications).

SBC RESEARCH TEAM

Allen Van Deynze
 Allison Krill-Brown
 Amanda Lima Vilela
 Angel Avalos
 Armando Garcia-Llanos
 Arnaldo Rios-Cruz
 Arsenio Ndeve
 Chandler Levinson
 Danyelle Forte
 Faryal Ali
 Gen-ha Park
 Gizaw Wolde
 Henry Alvarado
 Imtiyaz Khanday
 Kent Bradford
 Macarena Farcuh
 Nadia Bostan
 Oon-Ha Shin
 Pedro Bello
 Reagan Reed
 Samantha Hilborn
 Sheriff Seedy-Phaal
 Shiyu Chen
 Shuangshuang Liu
 Sirisupa (Trent) Sripolcharoen
 Terryn Hutchings
 Theresa Hill



SBC PRESENTATIONS

- Bradford, K.J. Understanding biological variation through population-based sensitivity thresholds. Invited speaker, President's Symposium, American Society of Plant Biologists, Washington, D.C., July 27, 2020.
- Bradford, K.J. Seed quality: Requisite for a better crop. Invited keynote speaker, Seed Stewardship in Post-COVID Scenario (webinar), MNS University of Agriculture, Multan, Pakistan, September 24, 2020.
- Bradford, K.J. Understanding Biological Variation: Extracting Order from Diversity. Invited keynote speaker, Get2Gether Conference of Dutch PhD students, February 2, 2021.
- Bradford, K.J. Presenter and Roundtable discussion panel member on topic "What are the roles of seed technologists to ensure sustainability in agriculture?", Asian Pacific Seed Association, Technical session for Standing Committee on Seed Technology, (online), November 22, 2021.
- Khanday, I. Clonal propagation of hybrid crops: making breeder's dream come true. Invited speaker at 82nd Annual Convention of California Seed Association, March 14th, 2022.
- Khanday, I. Creating seeds for the future: clonal, resilient, and high vigor. Invited speaker at Seed Central, UC Davis. December 8th, 2022.
- Van Deynze, AE and Zischke, J. Gene editing. American Frozen Food Institute. Feb 2020.
- Van Deynze, AE and Waweru, B. African Orphan Crops Consortium, alleviating stunting due to malnutrition one crop at the time. May 2020-online
- Van Deynze AE, Jay-Russel, M. Warburton, M. Brandl, Micalef and Melotto, M. Breeding Crops for Food Safety. Plant Breeding Innovation conference, USDA, FDA, EPA. Washington DC. Jan 2020
- Van Deynze, AE. Mechanical Harvesting is essential for Horticultural Products. Ag and Natural resources conference. Dec. 2020.
- Van Deynze, AE. Breadfruit and Jack Fruit Genomics. Plant and Animal Genome conference. Jan 2020.
- Van Deynze AE. USDA's Role in Plant Breeding Education and Mentorship. Sept. 2020.
- Van Deynze, AE. Genome editing: democratizing Science. AgriFood systems conference April 2021.
- Van Deynze AE. Seed Biotechnology Center. Institut Teknologi Del, Indonesia. Oct. 2021
- Van Deynze. AE. Breed Local and have Global Impact. American Society for Horticultural Science. Denver, CO. Aug. 2021
- Van Deynze, A.E. Gene Stacks: Plant Breeding tools. Taiwan Regulatory group. June 2022.
- Van Deynze, A.E. UC Davis Pepper breeding program. Student Collaborative Organic Plant Breeding Education (SCOPE) April, 2022.
- Van Deynze, A.E. Plant Sciences Careers. UC Davis Discovery undergraduate group. April, 2022.

- Van Deynze, A.E. Gene editing Plant Breeding tools. The Culinary Institute of America. June 2022.
- Van Deynze, A.E. Genomes of African Crops. Germplasm resources in Africa, Arusha, Tanzania. Oct.

SBC COMMITTEES

- Djordjevic, J. European Seed Association, member
- Djordjevic, J. California Seed Association, Vegetables committee
- Himmel, P. California Seed Association, Phytosanitary committee
- Khanday, I. California Seed Association Plant Breeding Committee
- Van Deynze. Msc Thesis Committee Rabindra Ramjittan, West Indies. August 2020.
- Van Deynze, AE. American Seed Trade Association Plant Breeding Emerging Issues committee 2020-2021
- Van Deynze, AE. American Seed Trade Association Sustainability committee 2021
- Van Deynze, AE. California Seed Association Vegetables committee
- Van Deynze, AE, California Seed Association Plant Breeding committee
- Van Deynze, AE. California Crop Improvement Association, Member at Large. 2020-2021

SBC PUBLICATIONS

- Akohoue, F., E.G. Achigan-Dako, C. Sneller, A. Van Deynze, and J. Sibiya. (2020). Genetic diversity, SNP-trait associations and genomic selection accuracy in a west African collection of Kersting's groundnut [*Macrotyloma geocarpum* (Harms) Maréchal & Baudet]. Plos One 15:e0234769.
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- Bello P.H.N. (2020) Analytical and Computational Tools to Assess Seed Quality and Model Germination Rates. MS Thesis. University of California, Davis, Davis, CA USA.
- Bello, P. and Bradford, K.J. (2021) Relationships of *Brassica* seed physical characteristics with germination performance and plant blindness. Agriculture 11, 220. <http://doi.org/10.3390/agriculture11030220>.
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SBC ADVISORY COUNCIL

The SBC Advisory Council announced expansion of its membership. As always, the SBC is grateful for their continued sage advice and support.

Jeff Zischke	Sakata Seed America (Chair)
Andy Lavigne	American Seed Trade Association
Bill White	White Seed Company and Seed Advisory Board
Charlie Brummer	UC Davis Plant Breeding Center
Chris Zanobini	California Seed Association
Dale Krolikowski	Germaines Seed Technology
Dan Gardner	S&W Seed Co
David Bubeck	Corteva and NAPB
Francois Korn	SeedQuest-Seed Central
Gail Taylor	UC Davis Department of Plant Sciences
Gary Hudson	Hudson & Associates Inc.
George Gough	Bayer Crop Science
Howard-Yana Shapiro	Retired from Mars Incorporated
Imtiyaz Khanday	Director of Research SBC
John Palmer	California Crop Improvement Assn
Kent Bradford	Director Emeritus SBC
Manuel Rosas	BASF Vegetables
Matthew Johnston	Syngenta
Rick Falconer	Rijk Zwaan
Rick Harrison	Driscolls
James Brusca	HM.Clause



PLANT BREEDERS: “INNOVATORS-IN-CHIEF”

With the world population projected to attain 9 billion by mid-century, it is imperative the seed industry and plant breeding contribute to finding ways to multiply world food production with other stakeholders, while using fewer resources, preserving the environment, and producing crops with higher nutrition and safety. Our contribution goes in part through education. SBC educational courses and our flagship program UC Davis Plant Breeding Academysm are tailored for the seed industry, and they are designed to fit in the busy agendas of working professionals. Our teaching model of “100 years of experience in the classroom” does not rely only on dry theory from a textbook and tired models with little relevance to your seed industry business. Instead, we offer interactive sections to “work on” applying the learning to real life situations. Thus, SBC courses are a rare opportunity, e.g., UC Davis Plant Breeding Academy curriculum is entirely focused on plant breeding, it has a practical approach, and it is taught by experienced Plant Breeders and active industry professionals.

Let’s talk about innovation and plant breeding. Continuous development, congratulations to all current and future plant breeders and scientists that made the first step to enroll in our renowned international UC Davis Plant Breeding Academysm and embark into further development of their plant breeding skills. Kudos to their organizations to recognize the needs to invest in developing from within their organizations, too. When I was in the industry and leading R&D teams, I found that, besides giving some structure and “freedom to express” to the teams, investing in your people and developing from within the organization is a great tool for employees’ engagement, as well as retention, which often translates to performance and the company bottom line. You all may have heard about cliché debate: “CFO: What happens if we train them, and they leave? CEO: What happens if we don’t, and they stay?”. Thoughtful leaders and HR executives these days understand that continuous development of their workforce is one of the keys to sustainable and successful businesses. Indeed, when I was just starting with a plant breeding career, often we would call plant

breeding “Art of Science”, recognizing the use of scientific disciplines like genetics and statistics but it also needed a bit of art to put so many things together into commercial products with added value towards growers and the value chain. Later, with intensive development of molecular biology and other tools, we tweaked it to “Art and Science”. But often, we neglect to recognize that plant breeders are working within a much broader external environment that includes growers, plant raisers, processors, retailers, consumers, thus the complete value chain and global nature of seed markets. The take home message here: plant breeders need to wear a third hat, that of a business person, too, thus the “Art and Science and Business” definition of plant breeding is prescribed!

Innovators-in-Chief

Setting up your plant breeding objectives aligned with the needs of your organization is likely the first thing to do before you initiate plant breeding efforts with often limited resources. In breeding we need to be able to see 10 years down the road. Of course, crop dependent, e.g., for leafy crops it could be shorter, for biennials crops could be longer than 15 years, but the key is to be visionary and “clairvoyant” and guess where the market would trend, with or without your influence. It may sound intimidating, and it’s true. But it really starts, besides mastering an “Art and Science” of plant breeding (which you should!), with knowing a seed business ecosystem; you should rely on your company marketers and processes but also take opportunity to see outside of your organization and talk for example, with a grower on their farms and in their packing sheds. When you hear first-hand about problems they face during crop production, harvest, processing, and shipping further down the chain, you may be more driven to innovate and try to solve their problems. One more thing, plant breeding objectives are also your choice! You can decide to be a follower, e.g., identify a market benchmark and make some incremental improvements (often called “me too” products), or you can decide to be a leader and set new standards for others to follow. The late Steve Jobs once said “Innovation distinguishes between a leader and a follower”.



Jovan Djordjevic
Seed Biotechnology Center
Director of Education

PLANT REPRODUCTIVE BIOLOGY
1106 EXTENSION CENTER DRIVE
DAVIS CA 95616
SBC@UCDAVIS.EDU

