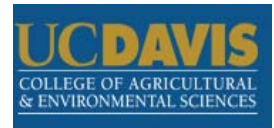




UC Davis Seed Biotechnology Center Ten Years of Service, Education and Research



Executive Summary

This year marks the 10th anniversary of the UC Davis Seed Biotechnology Center (SBC). The California Seed Association (CSA) and the California Seed Advisory Board (CSAB) along with the UC Davis College of Agricultural and Environmental Sciences (CAES) have been essential partners with the SBC since its inception. This is an appropriate time to assess the accomplishments and value of the SBC and to evaluate the benefits of continuing this partnership.

Since 2000, the CSAB has provided annual support for the SBC from an assessment on seeds sold in California. This funding was \$150,000 per year from 2000 to 2006 and \$200,000 per year from 2006 to 2010. This total of \$1.7 million from the CSAB was matched by salary support from CAES (\$1.35 million) and targeted fund-raising campaigns (\$1.6 million). In addition, the SBC received \$7.1 million from research grants and another \$1.25 million from other activities (courses, workshops other income). Cumulatively, the SBC has garnered \$11.3 million in funding to supplement the \$1.7 million from the CSAB, a 6.6-fold return on investment over the 10 years.

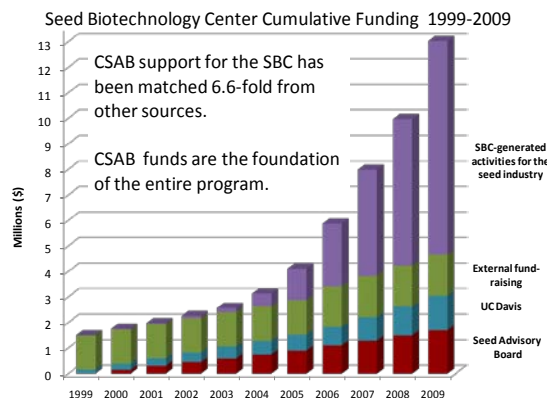
The SBC utilizes these funds to conduct public service, outreach, educational, and research activities that are relevant to the needs of the seed industry. Public service activities include development of a web-based isolation mapping program, economic studies of the California seed industry, co-existence workshops, and scientific input on diverse topics and policies affecting the seed industry. The SBC

hosts dozens of visitors and tours annually, providing an opportunity to inform them about California's seed industry. Educational activities include creation of the Plant Breeding Academy and offering professional development courses and workshops for continuing education. The SBC staff has published numerous peer-reviewed bulletins and reports about topics relevant to the seed industry. Research projects have developed genetic maps and molecular marker resources in seven major California crops, conducted gene flow studies in alfalfa and cotton to support co-existence and marketing of seed crops, tested transgenes for useful traits, and investigated seed germination, vigor, storage and dormancy. The SBC spearheaded the

establishment of a plant transformation facility at UC Davis that enables the research of dozens of UC faculty and external clients.

The original concept and the key to the success of the SBC has been a focus on partnership with stakeholders. The partnership established between UC Davis and the

California seed industry 10 years ago has returned significant value and benefits to both parties. The additional funds generated by the SBC are dependent upon the core CSAB funding and cannot replace it. CSAB funds also support public service and educational activities that simply would not occur without the SBC. Thus, continued support from the CSAB is critical to maintaining and enhancing the services and value that the SBC provides. We encourage CSA and CSAB members to continue their support for the SBC so that this partnership can continue to flourish.





UC Davis Seed Biotechnology Center Ten Years of Service, Education and Research



Introduction

The year 2009 marks the 10th anniversary of the UC Davis Seed Biotechnology Center (SBC). The California Seed Association (CSA) and the California Seed Advisory Board (CSAB) have been essential partners with the SBC since its inception. The CSAB is a state marketing order authorized by the California Department of Food and Agriculture to administer funds raised by an assessment placed on all sales of vegetable and field crop seeds in California. The CSAB, with the approval of the CSA, has allocated a portion of these funds to provide the core funding for the SBC's operations since 2000. The SBC could not have been established and would not exist today without the CSAB's continued support. The SBC leverages the core CSAB funding through grants, courses and other income to support research, education and outreach programs focused on areas of interest to the California seed industry. This report summarizes the establishment and mission of the SBC and describes the contributions that the SBC has made to the seed industry during its first 10 years.

Establishment of the SBC

From the start, the SBC was conceived as a partnership with the California seed industry. The first SBC organizing committee meeting held at UC Davis in the summer of 1996 included representatives from California seed companies, the CSA, the California Crop Improvement Association (CCIA) and UC Davis. This group supported the concept of a research, education and service center at UC Davis and identified its primary objectives: to facilitate access to and interaction with university researchers and to serve the California and world-wide seed industry with advanced training, research, education and information. The mission of the center would be to serve as the scientific research and outreach center for the California seed industry and beyond.

After discussing various options for naming the center, the Seed Biotechnology Center was selected. In 1996-99, the term "biotechnology" had a broad meaning that included diverse "biological technologies" that included seed treatments, marker-assisted breeding, tissue culture and other conventional methods as well as genetic engineering. Following the European regulatory market closure to genetically engineered (GE) crops in 1998 and subsequent public controversy, the term has now come to be associated more closely with transgenic or recombinant DNA methods. However, the SBC continues to define biotechnology as including a broad range of technologies that utilize biological principles, methods and organisms to achieve specific agricultural objectives. As such, the SBC focuses on broad-based enabling research and on fostering co-existence among all seed and commodity market sectors.

Support for the SBC was built through numerous meetings held around the state to promote awareness and later to raise operational and facility financing. A number of industry leaders were instrumental in moving the project forward. With their support and that of their companies, the CSA, the CSAB and the Dean's Office of the College of Agricultural and Environmental Sciences (CAES), the Seed Biotechnology Center was formally established in 1999. Initial support from the CAES included the opportunity for Professor Kent J. Bradford to devote half of his time as the SBC Director and funding for a part-time program representative, Sue Webster (now Sue DiTomaso) (Fig.1).

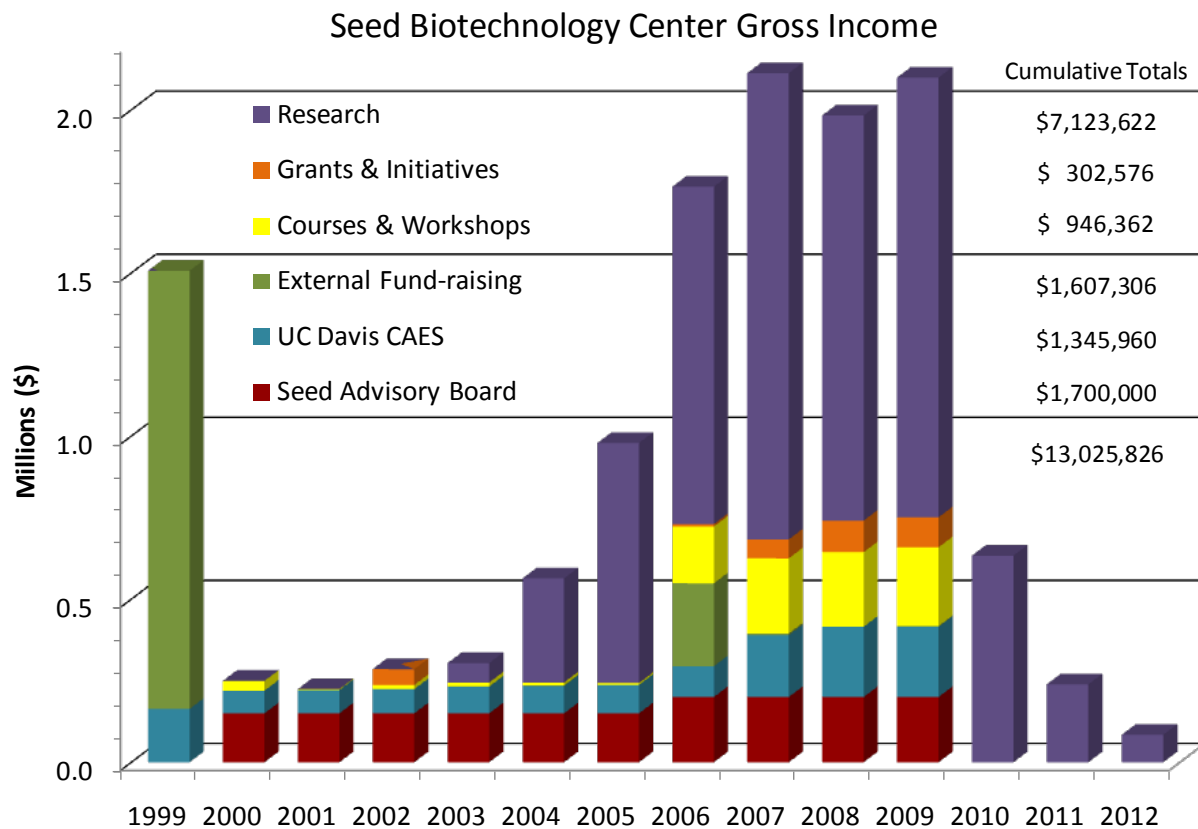


Figure 1. Annual funding of the SBC according to source since its establishment in 1999 and extending through current grant periods. Cumulative totals for each category and grand total are listed at the right.

The SBC approached the CSA and CSAB for additional operational funding. CSAB funds had been used primarily to support seed enforcement activities and the State Seed Laboratory in Sacramento, and some reluctance was initially expressed to dedicating funds to research and educational activities. It was considered to be within the authority of the CSAB to do so, as was subsequently specifically clarified in the California Seed Law. However, both the CSA and CSAB were hesitant to commit funds without evidence of broad support from the seed industry. At the same time, the SBC was seeking facilities on the UC Davis campus to allow it to expand its research activities. Since the CCIA, the official seed certifying agency in California, is also housed at UC Davis, the concept emerged of constructing a building to house both the SBC and the CCIA. It would have offices, seed testing laboratories, research laboratories, and seed storage facilities to support both programs. A campaign was initiated to raise the estimated \$1.5 million cost of this facility from stakeholders. Reaching that goal would be a tangible demonstration of industry support for the SBC.

The fund-raising campaign for the building was initiated in early 1999, and by the end of the year over \$1.1 million had been received in pledges. The campaign would eventually receive \$1.34 million from seed companies, foundations and individuals (Fig. 1). This demonstration of support led to approval in June 2000 of core funding of \$150,000 per year for three years from the CSAB. This enabled the SBC to expand Sue DiTomaso's position to full time and hire a professional researcher, first Dr. Bruce Thomas from 2001 to 2002 and Dr. Allen Van Deynze from 2002 to present. The funds from the building campaign subsequently

were merged with another campus project associated with the development of the UC Davis Genome Center. A small research facility on a fast-track timeline was planned, and Dean Neal Van Alfen of CAES enabled the expansion of this project to accommodate the SBC. The \$9 million facility was expanded to an \$11 million project to include office and laboratory space for the SBC (the CCIA decided not to move to this facility). An open house in October 2003 celebrated the completion of the Plant Reproductive Biology building, the current home of the SBC.

The CSAB has subsequently continued its support for the SBC with three-year contracts for \$150,000/year renewed in 2003, for \$200,000/year in 2006, and a one-year contract for \$200,000 in 2009 (Fig. 1). A 2004 stakeholder survey strongly supported expansion of the SBC's activities, and a "Grow the SBC" campaign in 2005-06 raised an additional \$400,000 to hire an Executive Director (Michael Campbell) and expand the SBC's service and educational activities over a three-year period. Together, these funds have supported core SBC staff who have garnered an additional \$8.3 million from courses, workshops, research grants and other activities that provide significant service and value to the seed industry. The SBC has leveraged \$1.7 million in CSAB funding to raise over \$11.3 million in funding from other sources to build facilities and conduct educational programs and research relevant to the California seed industry, a 6.6-fold return on investment (Fig. 1).

Public Service Activities

Many activities of the SBC provide broad benefits to the seed industry. Most of these are not associated with specific funding sources, so are largely supported by the core CSAB contract. Below are some highlights of these activities by the SBC over the past 10 years.

- **Scientific input on regulatory and policy issues.** The SBC serves as an independent scientific voice on a wide range of regulatory and policy issues affecting the seed industry. The SBC has worked closely with the CSA on legislative issues, such as on AB 541 which would have increased the liability of the seed industry. Other groups including the CDFA, the California Farm Bureau Federation, the American Seed Trade Association (ASTA), the Biotechnology Industry Organization (BIO), the Council for Agricultural Science and Technology (CAST) and the US Department of Agriculture (USDA) have benefitted from the scientific expertise of the SBC. SBC scientists have contributed to publications and commentaries that have been utilized by the USDA and other groups when formulating policies and regulations related to GE crops. The SBC has been active locally (e.g., with respect to local ordinances related to GE crops), nationally (e.g., by commenting on regulatory actions and revisions), and internationally (e.g., by participating in meetings negotiating the Cartagena Protocol of the Convention on Biological Diversity).
- **Co-existence of diverse production systems.** The SBC has initiated and facilitated stakeholder discussions in several crops to develop protocols to enable co-existence of conventional and GE crops. For both alfalfa and safflower, the SBC participated in discussions prior to introduction of GE varieties to provide scientific input and encourage consensus on mutually beneficial co-existence strategies.
- **Pollen flow studies.** The SBC has been involved in studies of out-crossing and gene transfer in cotton and alfalfa (see Research section). The more accurate data generated in these studies have been the basis for modifying seed certification standards for both crops.
- **Economic studies of the seed industry.** In 2003 and again in 2009, the SBC and the UC Davis Agricultural Issues Center conducted surveys and analyses of the scope of economic activity in the California seed industry. The most recent report estimated conservatively that California generates

over \$2 billion annually in global seed sales. These data are used by the CSA and other groups to highlight the importance of the seed industry to California's agricultural economy.

- **Web-based field isolation maps.** The SBC and CCIA collaborated in 2002 and 2003 to develop a web-based program that would allow seed producers to pin fields and identify isolation distances for different crops over the internet. The program became available in the 2004 crop year, and has been maintained and improved by the CCIA ever since. It features maps and drawing tools that make it easy to mark field locations, measure distances and alert other growers in the area of planting plans.
- **American Seed Research Summit.** Working with ASTA, the American Seed Research Foundation and the National Council of Commercial Plant Breeders, the SBC was a partner in convening an American Seed Research Summit in Chicago in September 2008. This broad-based group represented diverse components of the seed industry as well as university and government researchers. The Summit developed a white paper outlining key seed research and policy goals for the next decade that are now being pursued by ASTA and other organizations.
- **Specialty Crop Regulatory Assistance.** The SBC has been engaged since 2004 in efforts to develop a mechanism to assist specialty crops through the biotechnology regulatory process (www.specialtycropassistance.org). A model analogous to the IR-4 program for agrichemical registrations is envisioned that can assist developers of GE specialty crops with meeting regulatory requirements. A proposal to implement this at the national level is currently being evaluated by Agricultural Experiment Station directors.
- **Visitors and tours.** The SBC hosts dozens of visitors and tour groups annually, providing an opportunity to inform them about California's seed industry. These include CSA-organized tours for legislators and their staff, high school and college students, and diverse international groups visiting UC Davis. These contacts often lead to joint research or outreach activities, such as the Chile-California Program signed by Governor Schwarzenegger and Chilean President Bachelet at UC Davis in 2008.

Educational Activities

As an academically based organization, the SBC is committed to providing continuing education for the seed industry in all aspects of seed biology, quality, breeding and marketing. The SBC publishes bulletins and offers courses for seed industry professionals that enable them to keep current in the latest scientific advances impacting their work. The SBC is also active in the education of plant breeders and seed scientists both in traditional academic programs and through innovative new programs. Over 2000 participants have benefitted from SBC courses and workshops over the past 10 years. These activities are all self-funded through tuition or registration fees (Fig. 1).

- **Plant Breeding Academy.** Feedback from stakeholders indicated that there is a severe shortage of plant breeders receiving advanced degrees from the nation's academic institutions. At the same time, there are many professionals employed in private plant breeding programs who could become more qualified and effective breeders if they had additional knowledge and skills in genetics, statistics and breeding methods. The SBC established the Plant Breeding Academy (PBA) in 2006 to fill this gap in plant breeder training. Fifteen participants completed the first 2-year program in 2008, and 23 are currently enrolled in the second PBA class. There is global demand for this program, and the SBC recently announced its expansion to Europe beginning in 2010.
- **Seed Biology, Production and Quality.** This 2-day short course for professionals was first offered in 2000 and has been offered in alternate years since 2001. It provides a broad overview of the biology underlying seed production and quality as well as practical information on seed cleaning,

storage, testing and enhancement. SBC staff and expert invited speakers cover both basic information and the latest research results on each topic. Almost 100 participants attended the latest offering in March 2009, indicating continuing demand for this information.

- **Breeding with Molecular Markers.** This 2-day short course targets breeders and seed professionals who want to learn how to incorporate molecular (DNA- or protein-based) markers into their breeding programs. The course is continually updated as technologies change and includes invited experts and hands-on experience in data analysis. This course has been offered biennially since 2004 and continues to receive high enrollment.
- **Custom courses.** The SBC has the capacity to custom-design courses for specific clients. For example, updates on specific topics have been provided in-house as components of company research meetings or continuing education programs.
- **Workshops.** SBC staff are currently involved in a national research and extension consortium focusing on tomato and potato genetic resources and breeding (SolCAP; <http://solcap.msu.edu>). This program is delivering a series of workshops and creating public data resources to enable utilization of genomic resources in breeding programs in these crops.
- **Symposia.** The SBC has organized and hosted symposia that bring leading international scientists to California to enable local researchers to stay current in scientific developments relevant to seeds and breeding. Among these are *Biotechnology for Horticultural Crops: Challenges and Opportunities* in 2002, the Plant Sciences Symposium on *Translational Seed Biology: From Model Systems to Crop Improvement* in 2007, and the SBC 10th Anniversary Symposium *Seed Biotechnologies: Filling the Gap between the Public and Private Sector* in 2009. More than half of the participants in these symposia are from the seed industry.
- **Extension and outreach publications.** The SBC collaborates with other faculty and extension personnel in the UC to publish peer-reviewed bulletins, reports and articles on topics relevant to the seed industry. The *Agricultural Biotechnology in California* series of bulletins and fact sheets is particularly useful in providing a scientific background to discussions on this topic. A complete list of SBC publications can be found at <http://sbc.ucdavis.edu/Publications/>.
- **Plant breeding curriculum.** New technologies are rapidly altering the approaches utilized in plant breeding, and it is critical that academic curricula reflect these changes in industry practice in order to educate the next generation of plant breeders. The SBC is working with both public organizations (e.g., the National Plant Breeding Coordinating Committee and the Global Initiative for Plant Breeding) and private companies to support an international assessment of plant breeding curricula. The study will use a method that draws diverse opinions from a wide range of stakeholders and then refines that information into a consensus set of principles that will be broadly distributed.

Research Activities

SBC research activities are focused primarily on partnerships with industry collaborators that develop pre-competitive information that "lifts all boats." We concentrate on projects that will facilitate the activities that are central to the continuing improvement of crop and seed performance and to the competitiveness of the seed industry. Funding is received through various sources, including the USDA and particularly the UC Discovery Program that shares the project cost with private collaborators. SBC researchers have garnered over \$7.1 million in extramural research funds since 1999 (Fig. 2). Some of our research projects are highlighted below.

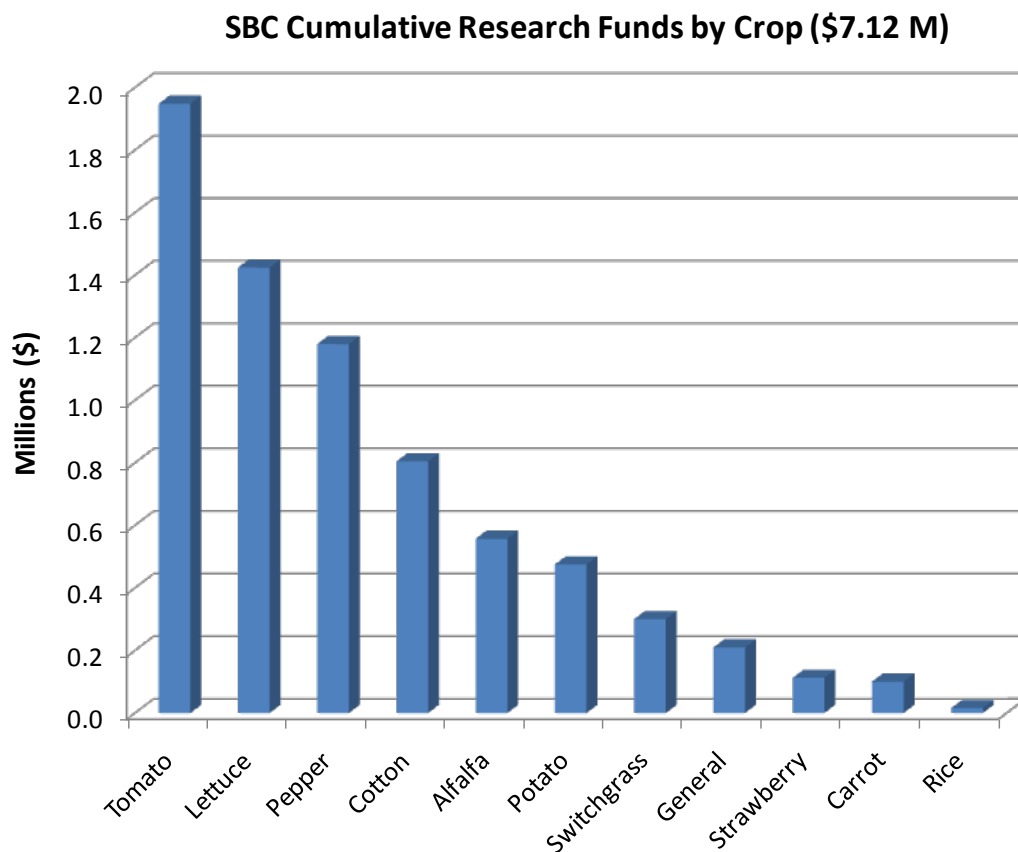


Figure 2. Extramural research funding garnered by the SBC since 1999 according to crop. “General” includes research that is not crop-specific.

- **Identification and application of molecular markers.** The SBC has been a leader in the development and application of new technologies to advance plant breeding. Some specific projects include:
 - **Tomato.** Cultivated tomato varieties have a narrow genetic basis, making it hard to identify variation that can be utilized in marker-assisted selection. DNA sequencing has enabled the identification of thousands of new markers in cultivated germplasm that can be utilized in breeding programs.
 - **Lettuce.** The SBC and UC Davis Genome Center developed a novel microarray that can simultaneously survey over 35,000 lettuce genes for DNA sequence variation among genotypes. This project has increased the number of mapped markers in lettuce from 2,000 to over 15,000 and enabled new approaches that will significantly advance lettuce breeding.
 - **Pepper.** A microarray-based approach has been developed to survey genetic diversity among cultivated and wild peppers and to develop high-density genetic maps associated with horticultural traits.
 - **Cotton.** The complex duplicated genome of cotton has made it difficult to identify useful molecular markers in commercial breeding germplasm. New high-throughput sequencing

- technologies employed by the SBC have enabled the identification of thousands of new markers for cotton and have clarified its genomic structure.
- **Potato.** With a duplicated genome and vegetative propagation, there is enormous genetic variation present in potato, but until recently little ability to effectively utilize it in breeding. The SBC and collaborators are identifying molecular markers associated with important traits that will facilitate potato improvement.
 - **Carrot.** Carrot has had little investment to date in developing genomic resources. The SBC is collaborating with carrot researchers to develop the first extensive DNA sequence database and marker-based genetic maps in carrot.
 - **Sunflower.** SBC researchers participate in the Compositae Genome Project, which includes sunflower as well as lettuce, artichoke, and many other crops and weeds. Genetic resources and markers developed through this project are being utilized for sunflower improvement.
 - **Transformation facility.** During its initial fund-raising campaign, the SBC spearheaded the establishment of the plant transformation facility at UC Davis in 2002 based on a contribution from the Ralph M. Parsons Foundation. This CAES facility has greatly enabled the research of dozens of UC faculty and external clients and is viewed as one of the best facilities of its type in the country.
 - **Transgenes.** The SBC has conducted projects to evaluate the effectiveness of transgenes in conferring specific traits. In one project, the SBC tested whether genes affecting drought tolerance in a model system (Arabidopsis plants) would work when transferred to tomato. A current project is evaluating whether drought and stress tolerance of switchgrass can be enhanced to improve its value as a biofuel crop.
 - **Co-existence.** Studies on gene flow in cotton and alfalfa have been critical both in regulatory evaluations and in identifying isolation distances required to achieve specific levels of genetic purity and therefore facilitating co-existence and marketing. In another project, growth of switchgrass is being evaluated in a number of environments in order to be able to predict whether it could become invasive if introduced widely into California.
 - **Seed biology and technology.** The SBC is conducting research on seed vigor testing funded by the ASTA and seed company partners, utilizing state-of-the-art technology for measuring respiration of individual germinating seeds. Projects are also investigating the physiological basis of seed priming and the effects of priming on seed longevity. The use of accelerated aging or controlled deterioration tests to predict seed longevity in storage is being assessed. Additional projects are focused on understanding the genetic and molecular basis of seed germination and dormancy.

Value of the SBC to the seed industry

The partnership established between UC Davis and the California seed industry 10 years ago has returned significant benefits to both parties. The investment by the CSAB to provide core staff and operational funding for the SBC has been magnified nearly seven-fold by SBC activities. Since 2000, the CSAB has provided \$1.7 million in core support to the SBC that has enabled the SBC staff to generate an additional \$11.3 million through its educational, research and fund-raising activities (Fig. 3). Together, these funds have supported cutting edge fundamental and applied research, educational programs for continuing human resource development in this rapidly changing field and public service activities that have broad beneficial impacts for the seed industry.

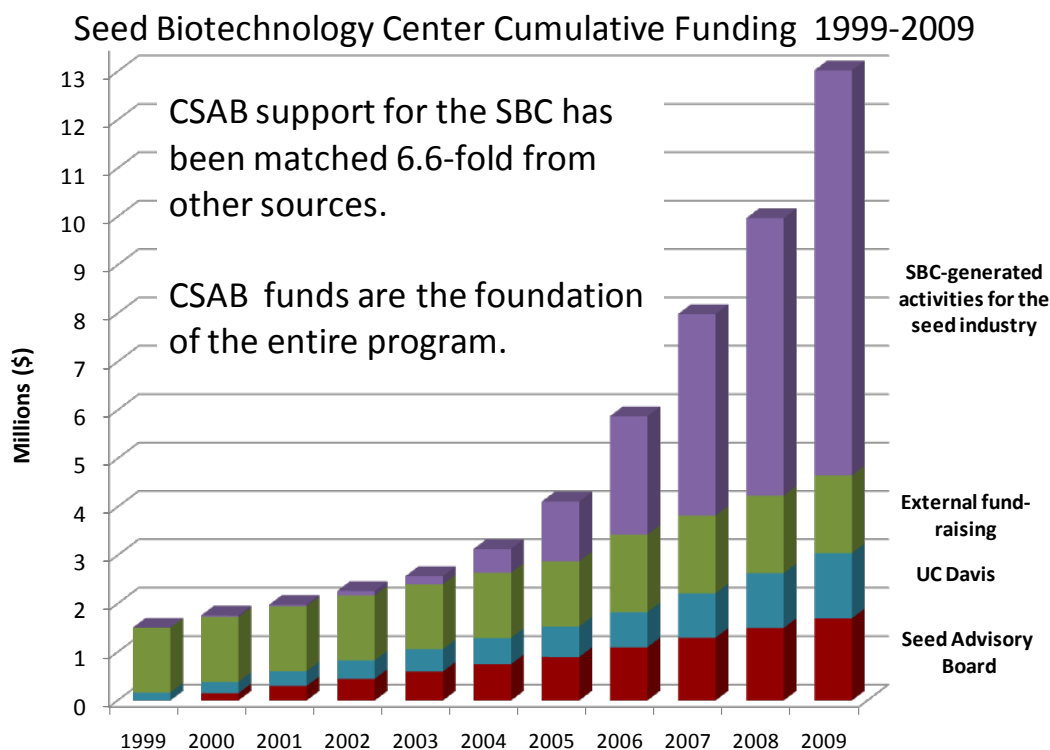


Figure 3. Cumulative funding for the SBC between 1999 and 2009. All SBC activities (research grants, courses, workshops and other activities) are pooled together.

CSAB funding is essential

It is critical to note that the additional funds generated by the SBC are dependent upon the core CSAB funding and cannot replace it. The core staff and activities supported by the CSAB make it possible to write the grant proposals and conduct the programs that generate additional income. It is extremely difficult to fund programs of this type in an academic environment strictly on extramural grant funds or self-generated income. CSAB funds also support public service activities that simply would not occur without the SBC. Thus, continued support from the CSAB is critical to allowing the SBC to maintain and expand the services that it provides.

A focus on partnership

The original concept and the key to the success of the SBC has been a focus on partnership with stakeholders, consistent with the Land-Grant University mission to be of service to society. The SBC takes this commitment very seriously and seeks to provide high value for the investment it receives. Stakeholder support is particularly critical when public funding to the UC is being cut and many academic programs may be eliminated. In this economic environment, academic programs that have active partnerships with stakeholders who financially support them are more likely to be retained.

The SBC is proud of what it has accomplished in partnership with seed industry stakeholders during its first 10 years. Numerous tangible benefits have been provided and a strong foundation has been established for future success. We encourage CSA and CSAB members to continue their support for the SBC so that this partnership can continue to flourish.