



STRATEGIC RESEARCH, EDUCATION AND POLICY GOALS FOR SEED AND CROP IMPROVEMENT

American Seed Research Summit Chicago, Illinois September 25-26, 2008

The complicated dynamics and vulnerabilities of the global food supply and distribution network have never been more apparent than in 2007 and 2008. Soaring commodity prices globally, record low levels of carryover stocks in most major food commodities, and unprecedented government intervention to restrict or ban exports all contributed to serious concern about the ability to supply even basic, subsistence food supplies to the world's increasing population. That concern caused world leaders to convene under the aegis of organizations such as the United Nations World Food Program (WFP), the United Nations Food and Agriculture Organization (FAO) and others to discuss measures for addressing the vulnerabilities of global agricultural production systems. A recent study projected that global demand for cereals will increase by 75% between 2000 and 2050 and global demand for meat will double (IAASTD, 2008). Global annual cereal production has increased by almost a billion metric tons since the 1960s, and must do so again during the next 30 years (FAO, 2002), underscoring the magnitude of the challenges facing the global food production network.

Central to each of these discussions was the availability of high quality seed required for the world's farmers to have the best possible chance for producing high yielding, valuable crops. A major factor in providing high quality seed is continued genetic improvement of crops through research and breeding. Overall, it is estimated that at least half of the yield increases attained in wheat and rice during the Green Revolution resulted from genetically improved varieties. Continuous genetic improvement has supported the steady increase in crop yields over the past several decades (Egli, 2008). The impact of improved breeding methods is particularly evident in the accelerated rates of increase in corn (maize) and rice yields associated with the introduction of hybrid varieties (Fig. 1). Further yield increases (or reductions in inputs) have resulted from genetically-engineered varieties with resistance to herbicides or insects

(Brookes and Barfoot, 2008). Advances in genomics and DNA technologies have enabled marker-assisted breeding that can cut the time and expense associated with varietal development (Collard and Mackill, 2008; Jena and Mackill, 2008). Together, the integration of these technologies has revolutionized plant breeding in the past decade (Moose and Mumm, 2008), making it feasible to set ambitious goals such as to double corn, soybean and cotton yields per hectare by 2030 while using one-third less inputs (Pollack, 2008).

Today, research and development in plant breeding are conducted in both the public and private sectors. Universities and government research organizations, such as the US Department of Agriculture Agricultural Research Service (USDA-ARS), have historically conducted basic genetic and genomic research, maintained plant germplasm repositories and administered long-term germplasm enhancement and varietal breeding programs. During the last several decades, plant breeding has evolved to the point that the majority of plant breeding in most agronomic and vegetable crops is now conducted by private companies who develop and sell improved plant varieties. Although plants can be propagated both vegetatively (i.e., by tubers, cuttings or grafting) and by seeds, the majority of US land devoted to agriculture is planted to annual plants that must be replanted each year by seed. Thus, the largest fraction of private investment in crop breeding and varietal development occurs in the seed industry, which is also involved in seed production, distribution and marketing. The seed industry is therefore a primary developer and user of plant breeding technology, creating varieties that can better withstand biotic and abiotic stresses and yield more while requiring fewer inputs. Additionally, seeds can serve as the delivery system not only for improved genetics, but also for new planting and production methods and crop protection strategies that improve the overall efficiency of agriculture (Halmer, 2004; Romeis et al., 2008).

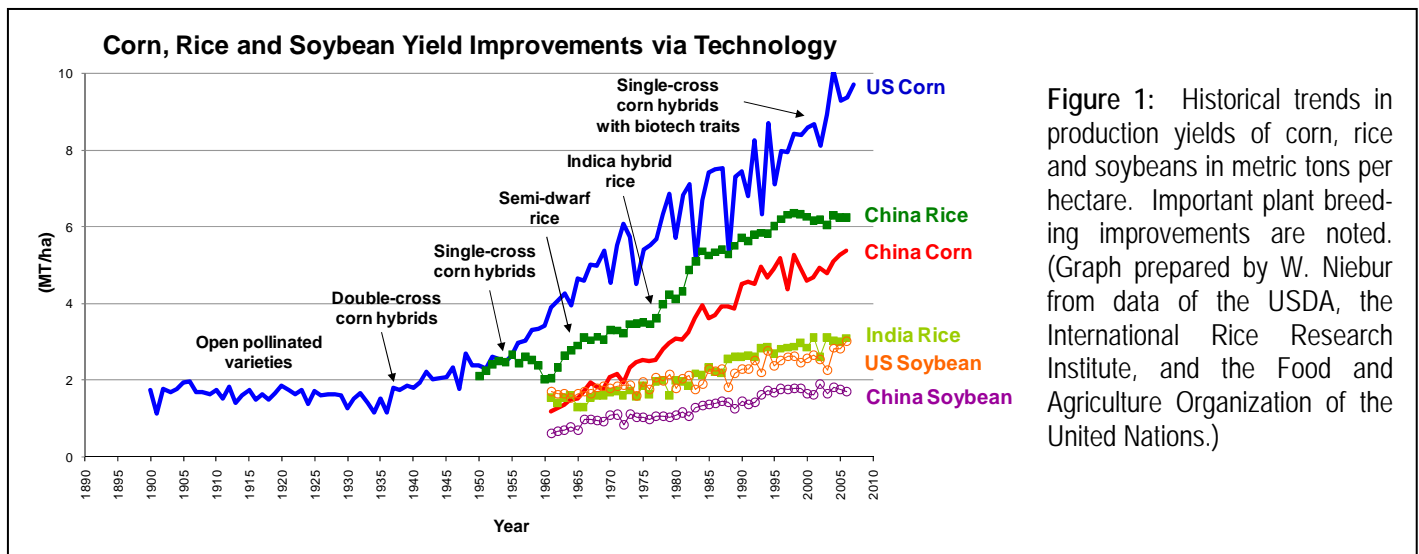


Figure 1: Historical trends in production yields of corn, rice and soybeans in metric tons per hectare. Important plant breeding improvements are noted. (Graph prepared by W. Niebur from data of the USDA, the International Rice Research Institute, and the Food and Agriculture Organization of the United Nations.)

With this in mind, the American Seed Trade Association (ASTA), the American Seed Research Foundation (ASRF) and the National Council of Commercial Plant Breeders (NCCPB) convened scientific leaders from industry, government and academia in an American Seed Research Summit to identify and prioritize a U.S. seed research agenda for the next decade. This meeting included research scientists, administrators and executives from major seed companies, the USDA and agricultural universities. The participants identified the critical research, education and policy challenges facing the U.S. seed and agricultural industries for the next decade and beyond. Participants in this summit and their affiliations are given in Appendix A and the meeting agenda is in Appendix B.

A conscious effort was made to balance different constituencies and crops in order to reach a broad consensus on the most pressing issues impacting seed research and policy that must be addressed to allow the agricultural system to meet future demands in a sustainable manner. A professionally facilitated workshop format was used, including key experts who framed the issues from the perspective of academia, government and industry. Over the course of two days, summit participants worked diligently through a collaborative and interactive approach to generate strategic priorities targeted at strengthening seed and plant breeding research. Key goals and strategies for accomplishing these priorities were identified and paired with specific action items needed to advance these agendas. Overall, there was a remarkable degree of consensus among the participants on the importance and relevance of the goals and strategies identified.

RESEARCH, EDUCATION AND POLICY GOALS AND STRATEGIES

The goals and strategies described below are the condensed opinions of the participants at the American

Seed Research Summit. The overall goals are listed by priority, along with some discussion and analysis of strategies for achieving them.

1. Strengthen public and private partnerships to accomplish national seed research priorities.

The challenges facing the American seed industry are not confined to either the public or private sector research communities and will require novel partnerships and collaborations to ensure success in achieving the summit priorities. The rapid evolution of modern plant breeding, genetics, germplasm development and seed biology has altered the landscape of the public-private partnership in research. However, with unified priorities (below) and new models for cooperation and collaboration, the strengths of both sectors can be brought to bear on the significant challenges faced by the agricultural industry.

The specific research priorities and scientific or policy goals identified at the American Seed Research Summit are listed in Appendix C. This broad and ambitious research agenda will require similarly broad and ambitious partnerships to address the issues simultaneously and at multiple levels. New models and mechanisms for pooling public and private resources, including both funding and information, are urgently needed. These models could include jointly funded public/private basic and applied research, creation of mechanisms for private to public information sharing, and public research cost-sharing through matching funds programs. Achieving these research and policy objectives through collaborative public and private research will provide the knowledge and tools needed to efficiently breed crops for higher yield, quality, resource efficiency and stress tolerance and to deliver high quality seeds with these improved traits into the marketplace.

The research priorities identified at the Seed Research Summit include the following (not necessarily in prioritized order; for more detail, see Appendix C):

- Conserve, characterize and utilize novel germplasm to preserve and broaden biodiversity in both natural and cultivated environments;
- Understand basic genetic mechanisms, including recombination, heterosis, gene expression, site-directed insertion, controllable gene switches, and design-driven genetic engineering platforms;
- Manage complex traits, including quantitative traits, gene expression and metabolic networks, physiological processes underlying phenotypic traits, and modes of gene action;
- Decipher the genetic basis of plant environmental responses, particularly responses to abiotic (drought, heat, cold, nutrients) and biotic (insects, pathogens, nematodes) stresses and genotype-by-environment interactions in general;
- Develop efficient high-throughput phenotyping and genotyping systems for trait evaluation and marker analyses, and integrate phenotypic and genotypic databases and analyses;
- Increase plant efficiency and quality to reduce inputs (water, nutrients, fuel), increase end-product utility or nutritional quality, enhance sustainability and limit ecological impacts;
- Create knowledge from information using intelligent systems analyses of large datasets, interactive databases, and simulation modeling;
- Improve seed health, quality and performance throughout production, processing, storage and distribution, and utilize seeds as a delivery system for multiple technologies;
- Continue to develop cost-efficient systems for risk analysis of products of new technology, particularly with respect to genetic engineering.

2. Coordinate and engage industry stakeholders to support stable funding for seed and breeding education, research and development.

Changes in seed research and innovation have dramatically strained the resources available to meet the current industry demands for qualified scientists and research capacity. To address this, a coordinated, industry-led effort must be developed to ensure that new and sufficient investment sources are obtained to vigorously address this ambitious research agenda.

Currently, much of the support for public research in plant genomics and plant sciences is provided through programs at both the National Science Foundation (www.nsf.gov) and the USDA (www.csrees.usda.gov; www.ars.usda.gov). These funding sources are becoming ever more competitive

and less reliable given the long-term nature of genetics and breeding research and uncertainty in the federal appropriations process. In addition, seeds play multi-level roles in germplasm conservation, crop propagation, and as primary global commodities, underscoring their essential role in agriculture and in multidisciplinary research. This changing agricultural industry dynamic provides the ideal opportunity for the American seed industry to coordinate a national research agenda to enhance its preeminent position for innovation and global competitiveness.

To accomplish this goal, the coordinated effort must focus on new and innovative funding opportunities to drive the research in plant physiology, genetics, breeding, pathology, agronomy and other key science areas that are fundamental to the seed industry's needs. Public and private stakeholders in the seed industry must explore new ways to support public research and its infrastructure both directly through collaborative partnerships and indirectly by expanding public research funding programs. All stakeholders, both public and private, share the objective of creating stable funding mechanisms to invigorate and sustain strong seed biology and plant breeding research and education programs. By developing a unified message and outreach program, organizations such as the ASTA, ASRF and NCCPB can effectively represent and promote these issues at the national and international levels.

3. Attract and develop a pool of diverse, high-quality plant researchers.

The science and methodology of plant breeding have been transformed by the integration of genomics and molecular markers into "classical" genetics and selection programs (Bernardo, 2008; Moose and Mumm, 2008). Marker-assisted and transgenic variety development approaches in combination with improved production technologies will enable yield and quality improvements without increasing resource inputs. To accomplish such goals, it is imperative that a continuous supply of educated and motivated plant scientists be recruited to meet the extensive demand that has been created by companies throughout the agricultural sector (Bliss, 2007).

Achieving this objective will require new investment in, and creative relationships among, land grant university plant breeding programs, government research sectors and private industry to ensure that the U.S. has a robust infrastructure for educating future generations of plant researchers, breeders, agronomists, pest control advisors and plant scientists (Gepts and Hancock, 2006; Morris et al., 2006).

Like many business sectors, agricultural industries are anticipating a large cohort of retirements in the next

decade and are expecting significant replacement needs. Novel approaches, such as the establishment of Centers of Excellence in plant breeding at public institutions, coordination of research capacities among universities and increased incentives and support for students, are needed to replenish the pool of high quality plant researchers to meet current and anticipated industry demands. Care should be taken to ensure that resources are maximized by coordinating educational and research programs so that the funds available are used for student-centered programs without unnecessary diversion of limited funds into equipment and infrastructure.

A key factor for attaining this goal is an emphasis on the scientific and professional opportunities that are available to prospective students in plant sciences in general and plant breeding in particular, along with expanded funding for pursuing advanced degrees in agricultural sciences. Internships in the seed industry and assistantships in academia, supported by the industry, not only provide additional training opportunities to students, but also are incentives to attract high quality people to the field. Extension education programs currently provided by several universities that educate professionals in the seed industry for positions in modern breeding programs should be expanded regionally and nationally.

The U.S. has enjoyed many natural advantages in agriculture due to its favorable geography for crop production. Going forward, the next generation of plant scientists and breeders must be cultivated and nourished with vibrant educational programs and attractive career paths.

4. Ensure that the regulatory system governing the development and implementation of new technology is efficient, effective and science-based.

Recombinant DNA technology (genetic engineering) has enabled the development of crops with increased productivity while reducing pesticide and fuel use and providing a range of environmental and economic benefits. In the 12 years since genetically engineered crops were introduced on a wide scale, an estimated \$34 billion in economic benefits have been realized by farmers around the world (Brookes and Barfoot, 2008). These benefits are based almost entirely upon only two categories of traits thus far, herbicide tolerance and insect resistance. New products in the developmental pipeline will expand on the current range of traits, at least for crops in which transgenic varieties are available (Castle et al., 2006; Damude and Kinney, 2008; Newell-McGloughlin, 2008). New agronomic traits such as improved nitrogen use efficiency and abiotic stress tolerance promise to shift

productivity/input ratios positively (Pathak et al., 2008; Witcombe et al., 2008).

A regulatory system that is effective, efficient and science-based contributes significantly to public confidence in the science that is the basis for today's agricultural biotechnology products. It is imperative that the industry continues to work to ensure that the regulatory process keeps pace with the rapid changes in the development of genetically engineered crops and with the accumulated experience with producing those crops.

5. Develop an education and advocacy program to communicate the value of seed and crop research to the public.

Citizens receive multiple benefits from seed research, including new products, lower food prices, agricultural sustainability, and ecosystem services. Crop genetic improvement and distribution via seeds are the original "green" technologies. Greater agricultural production is essential to meet the multiple demands of an expanding population and a reducing acreage for producing agriculture commodities. Between 1992 and 2002, U.S. crop output value increased by 26%, while the land area used for crop production actually decreased slightly (Anonymous, 2008b). Similarly, further increments in productivity will come largely from crops that are more efficient in using resources such as sunlight, water, and nutrients, rather than from expanding agricultural land use. With less than 2% of the US population directly engaged in farming, and the seed sector *per se* representing less than 5% of the total crop value in the U.S. (Anonymous, 2008a, b), few are aware of the critical importance of continued genetic improvement of crops and distribution of new varieties via seeds to meeting the global demands for food, feed, fiber, fuel, and, yes, flowers also.

Seeds are the wellspring of products to nurture both the body and the spirit, yet plant breeding in general and the seed industry in particular are often portrayed as part of the problem rather than the source of solutions to enable a sustainable future. The advantages of and potential for increasing agricultural productivity via crop genetic improvement must be better communicated to the public and to policymakers through more active outreach and advocacy programs by both public and private stakeholders. We have the opportunity and responsibility to ensure that scientists have the ability to utilize our best knowledge and technology in the service of agriculture and of society in general.

CONCLUSIONS

The American Seed Research Summit represents an important initial step in mobilizing the scientific and

educational resources of the U.S. to address the food and energy challenges of the near future. Scientific developments in the past 25 years have outlined clear paths for accelerating the pace of crop improvement to meet the dual demands of growing populations and rising standards of living. Through continued research and development, plant scientists and breeders can envision and deliver ways to achieve dramatic improvements in crop productivity and quality while reducing overall inputs and promoting sustainability. The question is not whether these achievements are possible, but rather how seed industry stakeholders will ensure that the resources are available to fully harness the knowledge, research and technology necessary to achieve the task at hand.

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Appendix A: American Seed Research Summit Participants

Name	Organization	Name	Organization
Industry		Government	
Anna Ball	Ball Horticultural Company	*Peter Bretting	USDA/ARS
Jonathan Bryant	BASF Corporation	Eliot Herman	USDA/ARS
Ted Crosbie	The Monsanto Company	Michael Fitzner	USDA/CSREES
Jack DeWit	Rijk Zwaan	Victor Raboy	USDA/ARS
Michael Dobres	NovaFlora, Incorporated	Kay Simmons	USDA/ARS
Robert Fraley	The Monsanto Company	Judy St. John	USDA/ARS
Larry Gautney	Sakata America	Christina Walters	USDA/ARS
Tim Gutormson	MidWest Seed Service		
Kater Hake	Cotton, Incorporated	Universities	
Matthew Johnston	Harris Moran	*Kent Bradford	University of California, Davis
Matthew Kramer	Ball Horticultural Company	*Michael Campbell	UC Davis Seed Biotech. Center
Mike Lassner	DuPont/Pioneer Hi-Bred	Dan Cantliffe	University of Florida
Mark McCaslin	Forage Genetics	Molly Jahn	University of Wisconsin
Roger Muren	Nunhems	Mark Lagrimini	University of Nebraska
William Niebur	DuPont/Pioneer Hi-Bred	Miller McDonald	Ohio State University
Ray Riley	Syngenta	*Jamie Miller	UC Davis Seed Biotech. Center
Kyle Rushing	INCOTEC	Gary Munkvold	Iowa State University
Gunter Seitz	AgReliant Genetics	Hiro Nonogaki	Oregon State University
David Stalker	Scotts Professional Seed	Alan Taylor	Cornell University
Steve Thompson	Dow AgroSciences		
Seed Associations			
*Fritz Behr	President, NCCPB		
*Ric Dunkle	Senior Director, ASTA		
*Andrew LaVigne	President and CEO, ASTA		
*Rob Robinson	President, ASRF		
*Gary Whiteaker	Chairman, Research, ASRF		
*Member of organizing committee			

Appendix B: Agenda of the American Seed Research Summit

American Seed Research Summit September 25-26, 2008 Hyatt Regency Chicago

Purpose and Outcomes

- To identify future needs, strategic priorities and critical gaps in research most important to the seed industry
- To review the current state of seed-related research and identify key research issues most important to the U.S. seed industry
- To develop strategies and an action plan to address key research issues most important to the U.S. seed industry

AGENDA

Wednesday September 24, 6:00 PM – 9:00 PM

6:00 – 7:00 PM – Informal Reception and Registration

Thursday, September 25, 8:00 am – 5:00 pm

7:00 AM – Continental Breakfast

8:00 AM – Welcome and Opening comments:

Rob Robinson, Master of Ceremonies

- *Anna Ball, President, Ball Seed Company*

8:20 AM – Introductions and Expectations:

Cindy Zook, Workshop Facilitator

8:40 AM – Keynote Presentations:

- *Bill Niebur, Pioneer Hi-Bred International*
- *Eliot Herman, USDA Agricultural Research Service*
- *Molly Jahn, University of Wisconsin*

10:00 AM – Defining Future Needs

10:45 AM – Research Priorities and Gaps

12:00 - 1:00 PM Lunch

1:00 PM – Looking Ahead

2:00 PM – Possible Strategies

4:00 PM – Report Outs/Action Plan Development

5:00 PM – Wrap-up and adjourn

5:30 - 6:30 PM – Reception

6:30 PM – Group Dinner

Friday, September 26, 8:00 am – 1:00 pm

7:00 AM – Continental Breakfast

8:00 AM – Opening & Highlights: Review the work from Thursday and the agenda for the day

9:00 AM – Keynote Address: *Robb Fraley, Monsanto*

10:00 AM – Future Direction: Focus on priorities, strategies and plans

10:45 AM – Moving into Action: Review the key issues and crystallize action plans.

11:30 AM – Report Outs and Next Steps: What are the key messages for the summit and what is our action plan?

12:30 PM – Wrap-up and Lunch: Andy LaVigne provides closing remarks and adjourns the group.

Appendix C. Research Priorities and Scientific or Policy Goals identified at the American Seed Research Summit. (Not in prioritized order, as all are important.)

Research Priority	Scientific or Policy Goals
Conserve, characterize and utilize novel germplasm	<ul style="list-style-type: none"> • Conserve and curate existing germplasm resources and expand collections • Characterize germplasm resources genotypically and phenotypically • Preserve biodiversity in both agricultural and natural environments • Utilize genetic diversity for improved productivity and yield stability
Understand basic genetic mechanisms	<ul style="list-style-type: none"> • Determine how to manage and direct genetic recombination • Determine the basis of heterosis and combining ability • Develop site-directed transgene insertion methods • Identify the determinants of gene expression efficiency • Develop gene switches for controlling trait expression • Design safe and efficient platforms for protein production in seeds
Develop efficient, high-throughput analysis systems	<ul style="list-style-type: none"> • Develop systems for high-throughput phenotyping of multiple traits • Develop molecular markers and high density genetic maps • Develop efficient and high-throughput marker analysis systems • Integrate phenotypic and genotypic databases and analyses
Manage complex traits, including quantitative traits	<ul style="list-style-type: none"> • Analyze the genetic basis for complex, multigene traits • Determine modes of action of genes and physiological processes in producing phenotypic traits • Analyze regulatory mechanisms for gene expression and metabolic networks • Control plant architecture to increase productivity
Decipher the genetic basis of plant environmental responses	<ul style="list-style-type: none"> • Identify and improve plant responses to abiotic stresses (drought, heat, cold, nutrients, etc.) • Identify and improve plant responses to biotic stresses (insects, pathogens, nematodes, etc.) • Analyze the basis of genotype by environment by trait interactions
Increase plant efficiency and quality	<ul style="list-style-type: none"> • Identify traits and methods to reduce inputs (water, nutrients, energy) while maintaining productivity • Increase nutritional content and/or product quality for end uses • Increase “value density” of products per unit of production area • Enhance sustainability and reduce ecological impacts of the complete agricultural system
Create knowledge from information	<ul style="list-style-type: none"> • Improve systems for management and analysis of large data sets • Apply intelligent information technology and systems analysis to genetic analyses • Develop standardized formats for distribution of information • Create interactive / interoperable databases • Develop and utilize simulation models of biology systems
Improve seed health, quality and performance	<ul style="list-style-type: none"> • Develop and implement production methods that maintain seed health and eliminate pathogens • Analyze the effects of new traits on seed physiology and quality • Develop new seed technologies for improved performance • Utilize seeds as multi-purpose delivery systems for diverse technologies • Investigate mechanisms of seed deterioration to improve seed longevity and germplasm conservation
Continue to develop cost- efficient risk analysis systems for products of new technologies	<ul style="list-style-type: none"> • Regulate traits on the basis of actual benefit and risk, not due to the breeding methods employed • Standardize regulatory data and analysis requirements • Understand the social science of consumer issues regarding agricultural technologies • Standardize relevant indices of sustainability