Farmer Leadership Drives Research Collaboration to Create a New 21st-Century Opportunity for Wheat

National Association of Wheat Growers
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Contents

The United Nations Food and Agriculture Organization estimates that global food production must double by 2050 to feed 9 billion people. As the world's largest crop, wheat is the staple food for 30 percent of the world's people, so it has a large role to play. Producing sufficient food in an environmentally sustainable manner on a finite land base in a changing climate is a challenge for farmers, scientists, private industry and the public sector.
(Science, July 2014)

Introduction

U.S. wheat yields remain stagnant compared to the increases enjoyed by other crops, especially corn. Wheat technology has just not kept up with crops like corn, soybeans and rice so it's no surprise that wheat acres have been losing ground for decades to these other crops, where farmers see more potential for return on their investment.

In just the last few years, however, there has been a resurgence in private-industry investment in wheat technology, and wheat farmers are encouraged by the potential production advances likely to result from private collaboration with the public breeding programs that have driven wheat technology for so many years.

Collaboration is the key word in wheat research, and it will likely continue to be in the future. Public researchers have always worked together, sharing germplasm through organizations such as Triticeae CAP, the International Wheat Genome Sequencing Consortium (IWGSC) and many others.

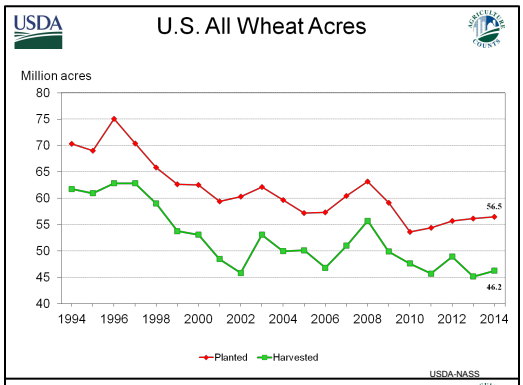
Now, as private companies get more involved, they are forming relationships with universities in order to access public germplasm to which they can apply advanced breeding tools, biotechnology traits and commercialization expertise
It is wheat farmers themselves, through their stated support for public-private collaboration on biotechnology and other methods of growing the U.S. wheat industry, who have inspired private industry to get more involved with wheat. Private companies know wheat farmers will invest more extensively in certified seed, crop protection products and other intensive management practices if technology ensures them a return on that investment.

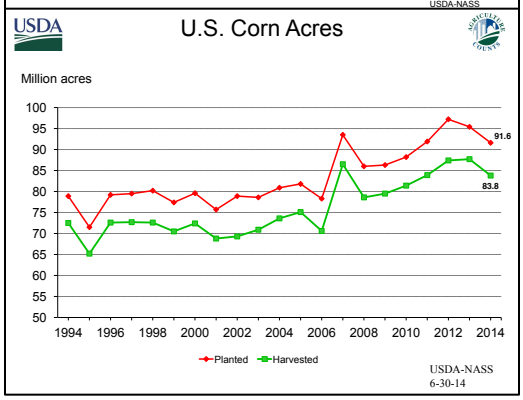
Wheat farmers also understand that growth of their industry will take money, and they are realistic enough to know that federal and state government will not be the

primary source of funding for wheat technology. Funding must come from many sources, including farmers themselves, and they are willing to make the investment if they can see the potential for long-term returns.

Wheat in Competitive Challenge for Acres and Yield

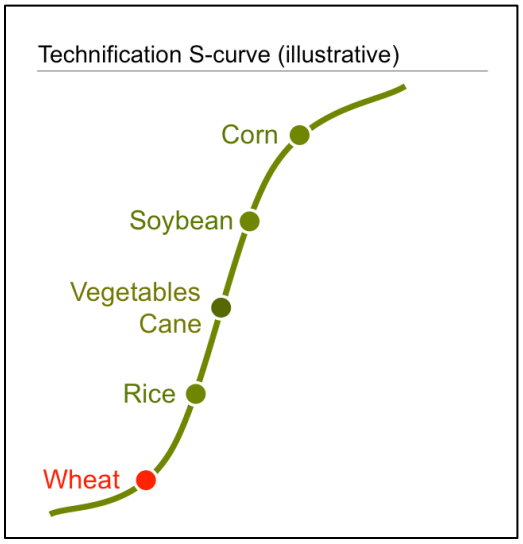
Wheat may lead the field as the most planted and traded crop in the world but corn and rice have surpassed wheat in tonnage produced. *(United Nations Food & Agriculture Organization)* Here in the United States in 2014, farmers planted approximately 21 percent fewer acres of wheat than they did 20 years earlier in 1994. During the same 20 years, U.S. corn acreage increased approximately 18 percent, almost as much as wheat declined.





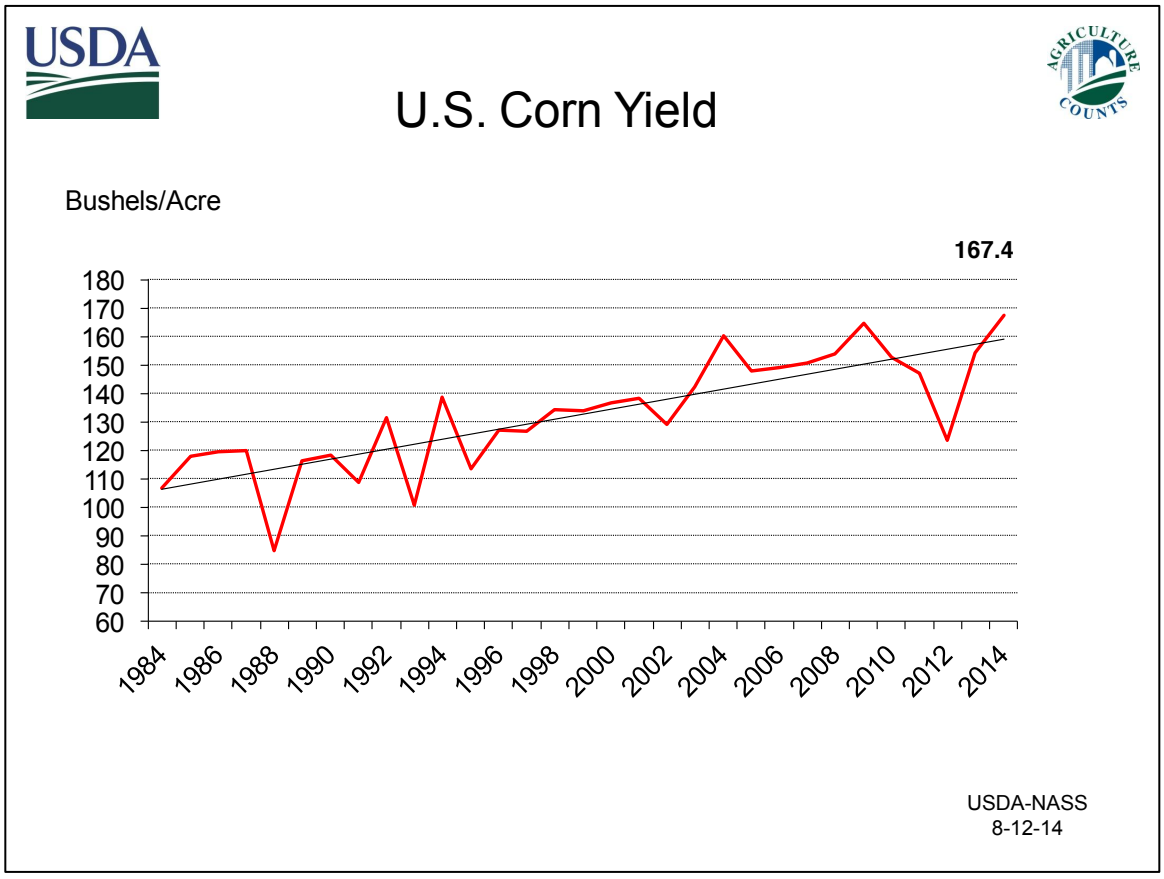
During that same 20-year period, average U.S. corn yields have increased approximately 67 percent, while wheat yields have increased much more slowly, approximately 35 per cent for winter and spring wheat and 18 percent for durum.

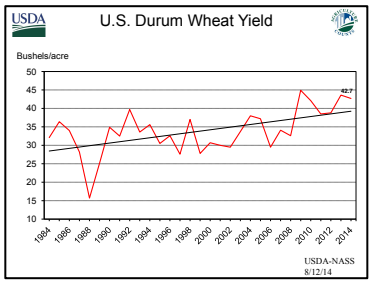
Yield increases in other crops are indicative of the higher investment in technology compared to wheat. (Syngenta graphic)

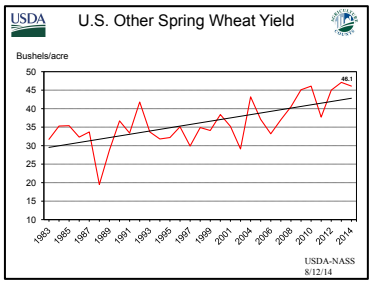


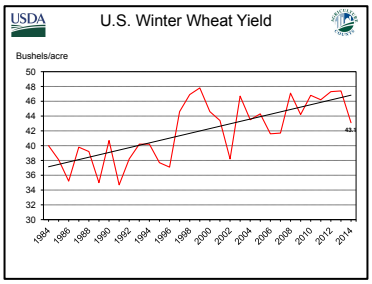
Data from the USDA's Economic Research Service shows a trend in wheat yields that has been below both corn and soybean yields nearly every year since 1990. The annual growth rate in corn yields are four times higher than wheat, and the longer this discrepancy continues, the harder it will be for wheat to compete. Wheat is being displaced across the Great Plains by corn and soybeans. The regions of northern North Dakota, western South Dakota and northwestern Minnesota, where corn and soybeans have increased at more rapid rates, displayed a correlating trend

of fewer wheat acres. Many counties indicated losses of 60,000 acres or more. Wheat acreage has seen a resurgence in southwestern Kansas and northern Montana. Traditional wheat growing areas of Washington have seen a wide variety of acreage trends.









Potentially declining wheat production is an obvious concern to the milling, baking and food industries for which wheat is an important ingredient. Millers need to feel confident that the nation' s wheat farmers can assure them of a consistently predictable supply of quality product. In addition to the supply issue, the more that wheat gets pushed to marginal acres by corn hybrids and soybean varieties that are adapted to climate extremes, the more vulnerable wheat becomes to weather, disease and even crop failure.

Negative Supply Curve Shifts for Wheat

The economic concept of "opportunity cost" is affecting wheat's competitiveness compared to other crops. Dr. Bill Wilson, agricultural economist, North Dakota State University, has compiled data documenting negative supply curve shifts for wheat production resulting from the prominence of biotechnology traits in corn and soybeans. A negative shift in a supply curve means that at the same price, less of a product will be produced than before, or conversely, producers will require a higher price to produce the same quantity of wheat.

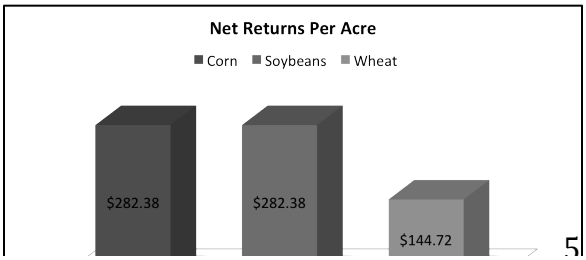
Wilson's data estimates that drought tolerance in corn and soybeans will result in a 60 cents per bushel opportunity cost for wheat production on the same land. In other words, to bring an acre from these drought-tolerant corn and soybean varieties back to wheat, the market price of wheat would need to rise 60 cents per bushel. Wilson estimated that the introduction of Roundup Ready 2 Yield soybeans in 2009 increased the opportunity cost of wheat production by approximately $1.49 per bushel of wheat. Those spreads could translate to significant costs for food companies and, if new technology continues to be introduced in other crops while wheat is left behind, those opportunity cost spreads will widen.

Graduating plant breeders and molecular biologists are drawn to the crops where the technology is and, if next-generation scientists do not see technology advances in wheat, they may choose to work in other crops that use the latest tools. An industry in decline will be less able to effectively advocate its policy positions before government, win public support for research investments, have sufficient leverage to secure favorable trade agreements, mitigate cost impacts from regulation or engage in strategic partnerships with others in agriculture. If wheat production does not advance, it is easy to see how companies developing new technology and products may focus their primary efforts on crops with larger markets and greater potential for return.

Farmers Make Planting Decisions Based on Expected ROI

Paul Penner, owner of Penner Farms, Hillsboro, Kan., and 2014 president of the National Association of Wheat Growers (NAWG) says that since farmers base their planting decisions on excepted return from a crop, wheat is likely to continue losing ground to corn and soybeans until wheat technology catches up.

The August 2014 University of Missouri Food and Agricultural Policy Research Institute reports that farmers' net returns per acre (gross market revenue



minus variable expenses) are approximately twice as high for corn and soybeans as for wheat.

"Corn and soybeans continue to make inroads into wheat acres, especially in areas that used to be considered fringe areas for those crops," Penner says. He points to shorter-maturity corn hybrids and drought-tolerant traits in corn and soybeans as examples of technology enabling growth in corn and soybean planting in areas that used to be wheat acres. "Wheat is becoming more of a locational crop in parts of the country where it used to be the dominant crop because other crops offer more potential for farmer income."

Public/Private Research Collaboration Can Stimulate Wheat Industry Growth

Speaking for wheat farmers, Penner strongly believes more public and private collaboration on research is the answer for growth of the wheat industry for farmers, private industry and end users. He says the increasing private investment in wheat and the growth in public-private collaboration that has been occurring since 2009 is very encouraging.

Even though wheat farmers do not yet enjoy the benefits of biotechnology as corn and soybean farmers do, conventional breeding techniques through public-private collaboration are bringing improved varieties with better resistance to diseases and pests. Marker assisted breeding and double haploid technology are making measurable differences in bringing better varieties to market faster. Wheat farmers are seeing improved genetic resistance to rust, scab, aphids, sawfly and other pests and diseases, as well as drought tolerance, cold hardiness, salt tolerance and nutrient utilization.

Wheat research has resided in the public sector for three primary reasons. First, as a self-pollinating species, wheat seed so can be saved from the harvest for planting the following year. With farmers planting "bin run" seed, there has been little incentive for private seed companies to develop seed. Second, the six classes of wheat make it a more regional crop more suited to local research done by universities than national research done by large agricultural companies. Third, has been the legacy of U.S. government investment in agricultural research and agricultural experiment stations and wheat breeding. Land-grant policies have promoted wide-scale, open access to new varieties, with little regard to financial return to developers.

Public Research Has Led the Way So Far

More than any other crop, public scientists have dominated wheat research. Public wheat breeders have developed the majority of cultivars grown by U.S. farmers, with state agricultural colleges and experiment stations accounting for

approximately 60 percent of the cultivars released in the 20th century. As a result of germplasm sharing and research cooperation among public universities, approximately 70 percent of wheat varieties planted today were developed and released by public wheat breeders. In addition, 90 percent of interspecific translocations involving the introgression of novel genes into cultivated germplasm that significantly affected wheat production were developed in public breeding programs. *(L.A. Mercado et al., 1996)*

According to the USDA's National Agricultural Statistics Service, the nation's highest producing wheat areas have been highly dependent on publicly developed cultivars. (Kansas: 62 percent; North Dakota: 64 percent; Washington: 88 percent; Nebraska: 90 percent). In comparison to other crops, 80 percent of cereal crop breeders are in the private sector and 20 percent public. In corn, 93 percent of breeders are in the private sector and 7 percent public. (*Crop Science, 2004)* Approximately 90 percent of U.S. soybean acres are planted to varieties developed from private programs. (*AgBioForum, 2003)*

Successes attributable to public research and breeding in wheat are numerous. Key examples include:

USDA-ARS Regional Nursery programs

Promoting germplasm exchange and wide-scale testing of new germplasm

Ug99

- Identification of genes, such as Sr35, that confers resistance to wheat stem rust race Ug99. *(Science, 2013)*

Grain Protein Content

- *GPC-1 gene for increasing grain protein content*
- Increased content of grain protein, zinc and iron through an NSC gene regulating senescence. *(Science, 2006)*

Genomic Tools for Pathogen Resistance

- Sequencing of the stripe rust, step rust and leaf rust genomes to identify genes the pathogen uses to attack wheat and subsequent marker assisted sequencing technologies of genes to confront those pathogens. *(J. Dubcovsky Euphytica 2011*)

Gene Cloning

- Cloning of agronomically important genes to help determine the alleles responsible for specific resistances enables more efficient introgression of a gene into multiple backgrounds using the allele itself as a diagnostic marker in marker-assisted selection (MAS). Ultimately, characterization of resistance genes according to their associated network nodes may serve as a viable conceptual framework for predicting the long-term curability of resistance gene combinations. *(J. Dubcovsky Euphytica 2011*)
- Development of multiple powerful genomic resources that have stimulated cloning efforts, including more than 3,000 molecular markers and physical maps of some 16,000 loci and sequencing of more than 105,000 wheat expressed sequence tags (EST.) *(Crop Science 2004)*

Molecular Markers

- Development of "perfect markers" based on the allelic variation responsible for traits such as glutenin genes for gluten strength; waxy genes for starch properties; puroindoline genes for hardiness; vernalization genes for vernalization or plant flowering requirements; RHt genes for semi-dwarf habit; and LR10 and LR21 genes for leaf rust resistance. *(Anderson et al., 1989; Briney et al., 1998; Beecher et al., 2002; Yan et al., 2003, 2004; Peng et al., 1999, 2004; Fueillet et al., 2003; Huang et al., 2003)*
- Development of closely linked molecular markers to yet unidentified genes with positive effects on quality characteristics and resistance to fungi, viruses and insects. *(J. Anderson 2000)*

Public Research Has Thrived on Collaboration

Teamwork among breeders and other researchers has been a foundation of public research in wheat for decades. "It's been a business of personal relationships," says Dr. David Van Sanford, University of Kentucky, and winter wheat co-chair of the U.S. Wheat and Barley Scab Initiative. "You associate certain people with breeding programs. There is a long-standing tradition for public breeders to exchange germplasm."

Following are significant examples of collaboration in wheat research among public institutions, private companies and farmer organizations:

International Wheat Genome Sequencing Consortium

The IWGSC, with more than 1,000 members in 57 countries, is an international consortium established in 2005 by a group of wheat growers, plant scientists and breeders. Assessing the fundamental information of the wheat genome will help

accelerate breeding pipelines and improve understanding of the molecular basis of agronomically important traits, such as yield and tolerance to abiotic and biotic stresses. *(Science, July 2014)* The vision of the IWGSC is a high-quality genome sequence of bread wheat that serves as a foundation for the accelerated development of improved varieties and that empowers all aspects of basic and applied wheat science.

U.S. Wheat Genome Project

Scientists at 10 U.S. universities are producing complementary DNA libraries from wheat or closely related species to maximize access to all genes in the wheat genome. Approximately 80,000 of these DNA clones are being sequenced to produce a large database of EST. Sequence comparison of these EST will be used to arrive at a minimum of 10,000 EST singletons, representing approximately half of all the gene motifs in the wheat genomes.

MAS Wheat

Scientists at 12 wheat breeding centers and research laboratories formed a consortium designed to increase the use of MAS in public wheat breeding programs. Funded by the USDA's Initiative for the Future of Agriculture and Food Systems, their work resulted in introgression by backcrossing more than 23 disease-resistance genes and 21 quality-related gene variants into approximately 100 adapted parents from different market classes. The project completed the introgression of valuable genes into 178 wheat lines across all classes of wheat, transferring powerful genomic research into growers' fields all across the U.S.

The consortium also developed new molecular markers, which were made publicly available in 23 scientific papers. The impact of MAS methods in wheat breeding was discussed in 73 presentations to wheat growers, industry and research meetings. The project stimulated integration of public wheat breeding programs and molecular laboratories, as well as development of scientists to implement MAS tools in breeding programs.

Triticeae CAP

The Triticeae Coordinated Agricultural Project (T-CAP) operates with a $25 million USDA National Institute of Food and Agriculture award to develop new varieties of wheat and barley. It merges barley and wheat breeders previously funded by the Barley CAP and Wheat CAP programs.

One of the main goals of T-CAP is to assess the impacts of climate changes on crop yields and identify genetic loci that can be incorporated into breeding programs to

improve the tolerance of barley and wheat to the many of deleterious effects that accompany change in climate. The team is also identifying favorable gene variants for disease resistance, water and nitrogen-use efficiency, and yield improvement from a large panel of barley and wheat germplasm. It is identifying new allelic variants and molecular markers and tagging them to accelerate breeding. Another important T-CAP goal is to develop a plant breeding education network to train doctoral students in plant breeding and provide educational opportunities for undergraduate students interested in plant improvement.

Wheat Genetics Resource Center

Located at Kansas State University, the WGRC is a national and international network for genetic studies in wheat. The center maintains a gene bank, along with evaluation and passport data, on 2,500 wheat species accessions and houses 2,200 cytogenetic stocks produced by a lifetime of work by many leading wheat scientists. The center has three priorities for advances in wheat breeding:

1. Collect, conserve and utilize germplasm in crop improvement for sustainable production by broadening the crop's genetic base.
2. Create and promote the free exchange of materials, technology and new knowledge in genetics and biotechnology among public and private organizations.
3. Sponsor graduate and postgraduate students and visiting scientists for academic training and advanced research.

WGRC germplasm releases include:

- Hessian fly resistant hard red winter wheat
- Leaf rust resistant hard red winter wheat
- Stress tolerant hard red winter wheat
- Leaf, stem and stripe rust and powdery mildew resistant durum
- Hard red winter wheat with resistance to powdery mildew and wheat soil borne and spindle streak mosaic viruses
- Septoria leaf blotch resistant hard red winter wheat
- Tan spot resistant hard red winter wheat
- Wheat streak mosaic virus and triticum mosaic virus resistant wheat
- Russian wheat aphid resistant hard white and hard red winter wheat

U.S. Wheat and Barley Scab Initiative

USWBSI manages 129 federally funded scab-related research projects in 26 states, encompassing 24 land-grant universities plus USDA-ARS and USDA-NASS. The

initiative's mission is to develop effective control measures that minimize the threat of Fusarium head blight (scab), including the reduction of mycotoxins.

Borlaug Global Rust Initiative

BGRI is an international consortium of more than 1,000 scientists from hundreds of institutions working together to reduce the world's vulnerability to stem, yellow and leaf rusts of wheat; facilitate sustainable international partnerships to contain the threat of wheat rusts; and enhance world productivity to withstand global threats to wheat security. Key components include a global wheat community with systems for cereal rust monitoring and surveillance; gene discovery; improved testing, multiplication and adoption of replacement varieties; training and capacity building; understanding non-host resistance to stem rust; and securing increased investment and coordination in wheat rust research and development.

The BRGI Durable Rust Resistance in Wheat Project represents collaboration among 22 research institutions around the world seeking to mitigate rust threats through coordinated activities that will replace susceptible varieties with durably resistant ones. The project also aims to introduce non-host resistance into wheat.

CIMMYT

Founded by Dr. Norman Borlaug in 1963, CIMMYT's Global Wheat Program provides elite material through its system of international nurseries to national breeding programs around the world. These wheat seeds have been put through CIMMYT tests wheat seed in different locations with different day lengths and environmental stresses. This testing identifies wheat varieties that are widely adapted to various agro-climatic conditions, resistant to a wide range of pests and diseases and yield more than their predecessors. More than 30 percent of the world's wheat varieties are either CIMMYT varieties – selected directly from the international nurseries – or descended from CIMMYT varieties. Its Global Wheat Program works with more than 200 research and breeding institutions globally, an agricultural research-for-development network that is one of the oldest and strongest in the world.

Its Seeds of Discovery (SeeD) program is using molecular and phenotypic characterization and informatics tools to increase biodiversity in seed breeding programs. Partnering with genebanks around the world, SeeD develops a diversity-driven bridging germplasm panel of lines that can be used as a multi-trait discovery and validation platform.

Heartland Plant Innovations, Inc.
Heartland Plant Innovations (HPI) in Manhattan, KS, is an innovative public-private collaboration that is developing advanced technologies for gene discovery, trait validation and crop improvement for wheat. The for-profit company began in 2009 with a grant from the State of Kansas Bioscience Authority and subsequent funding from private investors, including Kansas Association of Wheat Growers and several national agriculture and food companies.

HPI and Kansas State University (KSU) work together in many areas of wheat research leadership, including wheat research services, such as doubled haploid production, genotyping and crossing with native plant materials in Kansas State University's (KSU) wheat genetics resource center.

HPI and KSU are working together on development of a transgenic trait that could "increase wheat yields by 10-25 percent across all classes of wheat inn all parts of the world", says HPI interim president Rob Berard. He says the company is talking with potential seed-company partners to commercialize the trait. Should this be the wheat industry's first biotech trait, it would be a credit to the collaboration among the public sector, private industry and farmers that HPI embodies.

"This may be one of the first successful initiatives of it kind, with the primary purpose of developing and introducing new traits at a faster rate, not only using doubled haploid technology, but also working on new traits with the anticipation of the introduction of the first GE traits in wheat," says NAWG President Paul Penner, also a member of the Kansas Association of Wheat Growers.

The Kansas Association is the company's largest private investor. "Wheat leaders in Kansas wanted more wheat research and were interested in finding a method of accelerating wheat genetic, said CEO Justin Gilpin. "Wheat growers sought the grant from the state to get this company going, invested in it themselves and helped get the investment from private industry."

Investment Paradox for Farmers and Private Sector
There is a paradox to overcome if the wheat industry is to grow and catch up with other crops. For wheat to effectively compete with corn and soybeans for acres on the farm, farmers need to see the promise of significant and predictable higher yields. Until they see returns that compare to planting corn and soybeans, farmers will not invest in intensive management of their wheat crop. However, for private companies to invest in certified seed wheat genetics and crop protection technology that will increase yields and protect the crop from disease and pests, they need to

see that wheat farmers are willing to invest more in intensive management of wheat.

On the end-use side of the spectrum, farmers need to see the elimination of potential yield drag – or at least be compensated for it – if they are to plant varieties with high-quality end use properties such as protein, absorption, mixability, etc.

Collaboration Now Extending to Private Sector

While working together has been a foundational principle among public wheat researchers for decades, future research to accelerate growth of the wheat industry now depends on increasing investments in research and extending partnerships beyond the public sector to include private industry. This includes technology providers, such as seed companies, as well as end users, such as millers.

In addition to sharing of germplasm, traits, intellectual property and scientific knowledge, future public-private collaboration must also include a broader base of financial support for research across the spectrum of wheat stakeholders, including the federal government, land-grant universities, private agricultural and food companies, foundations and wheat farmers themselves.

Accomplishing both the farmer's need for higher yields and private industry's desire for more farmer spending on wheat is an outcome that can result from the growing alliance on wheat research now underway among private companies and public institutions.

NAWG and U.S. Wheat Associates (USWA) were strong advocates for more private investment in wheat research, and it is now occurring. Starting around 2008, companies throughout the world began investing more aggressively in wheat research and development through mergers, acquisitions and collaboration with the public sector.

Private companies have signficantly stepped up their investment in wheat research in recent years. Marker-assisted breeding, doubled haploid breeding and marketassisted recurrent selection have reduced the breeding cyle from 10-12 years to 6-7 and allowed for simultaneous selection for traits relevant to specific market areas such as yield, disease tolerance and baking quality.. arsecut the breed

Rising wheat prices, growing global demand for protein, increased grower use of certified seed and the obvious need for a technology infusion to make wheat competitive with other crops are key factors driving the surge in private investment

in wheat.

Farmers Call for More Technologically Stimulated Private Sector
Increased private investments were stimulated, in part, by leadership and encouraging signals from US farmers and NAWG.

In 2006, NAWG, the North American Millers Association, USWA and the Wheat Export Trade Education Committee published a paper warning that U.S. wheat production faced declining acreage and production; slower yield growth compared to other crops; relatively poor net margins for producers; very slow growth in domestic markets and virtually no growth in export markets. The industry held a series of Wheat Summit meetings for representatives of the various wheat industry sectors to develop joint recommendations on several fronts, including research priorities, public-private partnerships, and cross-sector activities to address these needs in wheat. *(Addressing the Competitiveness Crisis in Wheat, June, 2006)*

One outcome of the 2009 Wheat Summit, to further inspire more private involvement in wheat research, was the adoption of policy advocating cooperation between land-grant universities and private companies in order to develop improved wheat varieties. Entitled "Principles of Collaboration in Wheat Breeding and Biotechnology," wheat farmers, through their organizations, NAWG and USWA, urged state wheat commissions, wheat breeders and land-grant universities with public wheat breeding programs to follow specific guidelines when developing partnerships and agreements with private companies.

Colorado Association of Wheat Growers Executive Director Darrell Hanavan, who helped author the principles, said the intention was to ensure that public wheat breeding stayed strong. "We were concerned that public programs could be lost, but now we know they remain strong primarily through their ability to continue to exchange germplasm."

Recognizing the benefits and value that could be created within the wheat chain through the prudent application of biotechnology, U.S. wheat producers in 2008 announced their support for commercialization of transgenic wheat traits, contingent on thorough review and a commercialization plan that created minimal market disruption. This statement of "Wheat Industry Biotechnology Principles for Commercialization" stated that U.S. wheat farmers "will work diligently to assure that commercially achievable customer preferences are met."

In 2009, nine organizations representing wheat farmers and millers from the U.S., Canada and Australia publicly supported the future commercialization of biotechnology in wheat. This became known as the "Trilateral Statement on Biotech Commercialization."

The wheat organizations amended the statement in 2014 to acknowledge the numerous private investments in wheat research since 2008. These investments ranged from advanced breeding techniques, such as marker assisted breeding and double haploid technology, to biotech traits that can improve both the productivity and end-use qualities of wheat.

"We envision both biotech and non-biotech wheat coexisting with our current production grain handling, exporting and processing sectors to meet specific customer demands. We support choice and are committed to ensuring customers have access to both biotech and non-biotech wheat delivered through reasonable tolerance levels. We recognize that we are still at the early stages of a process that could last up to a decade, but we remain committed to responsibly advance wheat innovation." *(Statement of Canadian, American and Australian Wheat Organizations, June 2014)*

Wheat industry leaders including NAWG, USWA and the Wheat Innovation Alliance (WIA) and are the North American Millers' Association (NAMA) are optimistic that this and future increased private-public collaboration will lead to the development and commercialization of the first biotech wheat within the next 10 years.

NAMA advocates that "steps must be taken now to clear the way for the commercialization of biotech wheat as soon as feasibly possible. Biotechnology is one scientific tool that can improve food quality, safety and sanitation; increase production efficiency; advance sustainability through judicious use of water and agricultural nutrients; and help meet growing domestic and world food demand. NAMA members will utilize grains grown using science-based technologies that are equivalent in nutrition and safety to traditionally grown crops." *(www.namamillers.org/issues/biotechnology/nama-position-on-biotech-wheat)*

NAMA Director of Government Relations Sherri Lehman says the organization is confident that there will be eventual public acceptance for biotech wheat. She points out that consumers already accept genetic modification in medicine, and they will in bakery products too when they see a personal benefit, such as better prices, more variety and nutritional advantages.

Private industry is also recognizing the work of the WIA in preparing the groundwork for public acceptance of biotech wheat. "Farmers have to be pulling for biotech or you don't have a product, says Dr. Claire CaJacob, global lead for wheat research at Monsanto. "We need confirmation that there is support from the industry. Without encouragement from farmers for technology investments, the wheat industry would be harmed by other crops taking over traditional wheat growing areas," she said.

Soybeans Taking Over Traditional Wheat Growing Areas

The highly regional nature of wheat germplasm and research is also a key factor in national and international companies seeking to collaborate with state universities. "When private companies want to come into a new area, they rely on regionally adapted germplasm and pre-breeding activities of public researchers," says Justin Gilpin, CEO, Kansas Association of Wheat Growers. "Their investment would be much higher if they had to start from scratch. Access to regionally adapted germplasm and breeding programs at public universities is a compelling driver of private intestment."

Universities entering into alliances with the private sector typically make their germplasm available on a non-exclusive basis, which maintains the tradition of open germplasm exchange. This is not a limiting factor to companies, as they are developing integrated cropping systems, such as adapting their proprietary seed treatments and crop protection products to specific wheat genetics, which expands their markets for both seed and crop protection products.

Private Investment is Underway

Following are examples of the recent acceleration in private investment in wheat:

<u>2009</u>

- Monsanto aquired Montana-based WestBred, a premier wheat germplasm company.
- Bayer CropScience expanded its seeds and traits business to include wheat and made several moves to advance its wheat business. The company formed a partnership with Commonwealth Scientific and Industrial Research Organization (CSIRO), a leading Australian wheat research organization.
- Bayer CropScience acquired U.S. biotech firm Athenix, which had transgenic wheat reisisant to chemicals and pests in its pipeline. The company also formed a parnership with Ducks Unlimited to expand research into winter wheat varieties apapted to prairie climate conditions.

2010

- BASF and Monsanto expanded their biotechnology research collaboration to include biotech wheat.
- Monsanto acquired interest in leading Australian cereal breeder InterGrain, which is owned by the Australia state government. Focus of the collaboration is yield increases, disease resistance, drought tolerance and improved end-use qualities.
- Monsanto and Australian biotechnology company Hexima Limited announced collaboration on anti-fungal research in wheat.
- Syngenta entered the hybrid wheat business, leveraging its hybrid barley technology developed in Europe. Syngenta and CIMMYT, an international wheat research organization, form a public-private partnership to develop native and biotech traits, hybrid wheat and to integrate seed and crop protection products to increase wheat yields.
- Bayer CropScience and Evogene of Israel began collaboration to use native and biotech traits to improve wheat varieties.
- French company Limagrain Cereal Seeds launched a North American wheat breeding and seed development program. The business unit is a joint venture with Arcadia Biosciences, which is researching nitrogen-use and water-use efficiency in wheat.
- Monsanto entered into agreements with two universities, Kansas State University and Virginia Tech to begin sharing technology and germplasm on a non-exclusive basis guided by the principles of collaboration endorsed by the NAWG and USWA Joint Biotechnology Committee.
- Bayer and the University of Nebraska formed a non-exclusive collaboration through which the university provided access to its germplasm and Bayer established an endowed chair in wheat breeding.

2011

- Driven by U.S. support for biotechnology, German company KWS Lochow acquired the wheat germplasm assets of two American companies, Great Lakes Cereal Grains of Colorado and Sunbeam Extract Co. of Ohio, and consolidated its U.S. activities into a new company, KWS Cereals USA.
- Arcadia Biosciences received a $1 million grant from the U.S. National Institutes for Health to develop wheat with a high level of resistant starch to promote colon health.
- Bayer CropScience licensed germplasm from RAGT Semences of France and provided RAGT with options to license Bayer wheat traits. Bayer also entered a non-exclusive agreement with South Dakota State University (SDSU)

through which the company was granted access to SDSU's spring wheat germplasm and the university received funding for advanced education in wheat breeding, including an endowed chair in wheat breeding and genetics.

- Dow AgroSciences acquired assets from Northwest Plant Breeding Company in Washington and announced plans to expand its Hyland Seeds certified wheat seed program in the Pacific Northwest. The company also began exchanging germplasm with Australian wheat breeding company HRZ and providing HRZ access to Dow technology.

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- Limagrain Cereal Seeds, the Idaho Wheat Commission and the University of Idaho began a public-private alliance to breed new wheat varieties for improved productivity and tolerance to disease and stress. The Idaho Wheat Commission created two faculty research endowments at the university, and Limagrain funded an endowment for cropping systems research and graduate training at the university.

The Private Perspective

North American Millers' Association

NAMA member companies operate mills in 38 states and Canada, accounting for more than 90 percent of the wheat industry's total production capacity. The organization has a primary goal of ensuring a plentiful supply of top quality grains, produced in the most efficient, sustainable and safest way possible, NAMA is a strong supporter of research to assure consistency in wheat quality through research into areas like disease resistance, milling and baking quality and pre-competitive agronomic traits.

It provides financial and technical resources for wheat research on many fronts, including grants to university breeding programs, support for USDA wheat quality labs, the National Wheat Improvement Committee, the Wheat Quality Council and the U.S. Wheat and Barley Scab Initiative.

According to Benjamin Boroughs, director of regulatory and technical affairs, "Public private partnerships are a critical step towards faster commercialization of superior wheat varieties. The private sector has experience with high throughput sequencing and marker assisted breeding and emphasizes a team based approached to plant breeding. The adoption of these methods, along with increased funding, will allow public sector breeders to more efficiently introgress traits such as disease resistance into their elite varieties which farmers demand."

Boroughs cautions that the increasing private support for wheat research should not be seen as a justification for further cutbacks in public funding support. "Plant breeding is a long-term process, and wheat research can't be driven by short term market cycles. Universities, as well as state and federal labs, must maintain the capacity and expertise to respond to crises and the geographic diversity to provide for a truly national wheat crop."

Limagrain Cereal Seeds

Limagrain, an international, farmer-owned cooperative headquartered in France and the leading cereal seed company in Europe. The company brings a global wheat germplasm base and strong history of public-private collaborations to the US through its subsidiary, Limagrain Cereal Seeds (LCS). LCS is collaborating with numerous U.S. land-grant universities on breeding and research that will benefit the

company, the universities and wheat farmers. These collaborations range from simple germplasm exchanges, to licensing of public varieties, to innovative collaborative breeding projects in which varieties are co-developed and royalties shared. In this last case, universities gain benefit from access to company germpalsm, marker technologies, doubled haploid technologies, and regional testing programs.

Dr. Jim Peterson, formerly a wheat breeder at Oregon State University and head of the National Wheat Improvement Committee (NWIC), is the vice president of research with Limagrain's North American headquarters in Fort Collins, Colo. He noted several factors contributed to companies investing hundreds of millions of new dollars in wheat research. 1) The 2006 wheat summit was the industry's "call to arms, recognizing both the decline in public research funding and critical need for new investments in wheat research to stay competitive with other crops; 2) The 2009 Tri-Country Statement was an important message of support for commercialization of biotechnology and GM wheat development. 3) Several major universities had begun to enforce PVP and charge seed royalties on their varieties, which increases chances for value-capture on private varieties. 4) Rapidly decreasing cost for application of new biotechnologies, such as for molecular markers. Peterson also noted the evolution of variety development and commercialization from the public sector to the private sector in other crops. The private sector brings new perspectives on research and business, such as looking to advance wheat beyond a commodity to be considered as a high-value food ingredient.

"Universities are inherently not skilled in agricultural business, or business practices, and have difficulty with enforcement of intellectual property rights and Plant Variety Protection; all of which can mean missed opportunities in deploying new technologies, new products, new traits, or new varieties" he says. "This is especially true with regard to managing GM traits. Universities can do the research, but will be unable to bring GM traits to market due to the complicated and costly de-regulation process and their inability to accept liability in commercialization.

Peterson believes private investment and collaborations can keep the public sector involved in wheat breeding long term and that each can benefit from the other's strengths. "While companies provide universities with access to global germplasm, novel traits and more rapid breeding strategies, universities provide expertise in local adaptation of varieties to local cropping systems. Universities develop localized information packages, including seeding rates, timing, crop rotation and crop protection programs that growers need to complement new genetics."

Another value that universities bring is communication and feedback from local farmers. “Companies want interaction with state wheat commissions, grower associations, advisory groups, and universities facilitate those connections. Growers also need to be part of, and invested in, public-private partnership. ,” Peterson says.

Syngenta

A key focus of collaboration, according to Syngenta, is to better align the demands of the supply chain, which has a five- to 10-month pulse on consumer preferences, with the ability of breeders to deliver the desired product, which typically takes about 10 years.

Rollie Sears, North American cereals R&D manager for Syngenta, says that the public researchers in wheat have a tradition of cooperation among themselves that is now extending to the private sector, including more involvement by wheat growers and private companies with the NWIC, the organization that fortifies the nation’s wheat improvement research capacity.

Universities are in need of supplemental funds for research and development and companies are obliging. Farmers planting more certified seed and investing more in wheat inputs is an incentive for companies to collaborate with universities. “We have tripled our investments in marker and doubled haploid technologies in the United States,” Sears said. “We collaborate with universities to fill holes in the seed portfolio, and we see more opportunity for return on that investment.“

Public collaboration in wheat has been more widespread than other crops, governed by agreements such as the Wheat Workers Code of Ethics and material transfer agreements among universities. Sears hopes more private involvement will not restrict cross-institutional collaboration.

“Open exchange of germplasm has allowed public breeders to make crosses and develop new varieties without restriction on release of new varieties. Germplasm exchange has been unique in the wheat industry, and restricting exchange due to intellectual property concerns would slow genetic gain. Germplasm exchange governed by lawyers is not what anyone wants,” Sears said.

Bayer CropScience

To stimulate collaboration with private industry, the University of Nebraska-Lincoln (UNL) formed NUtech Ventures and, in 2010, launched a partnership with Bayer CropScience that gave non-exclusive access to the university’s germplasm. In return, Bayer funded the first presidential chair at the University of Nebraska, named in

honor of Nebraska wheat growers, and agreed to support the university's research and education programs. Bayer established its first North American breeding station near Lincoln, providing jobs, student internships and a major breeding effort to increase progress in creating new varieties and access to technology.

The agreement follows the university's long-standing arrangement with BASF, which provides the company access to Clearfield® technology. UNL also partners with ConAgra for testing wheat cultivars and improved wheat quality.

In announcing the collaboration with UNL, Bayer CropScience stated: "We recognize the expertise that has gone into developing UNL's breeding program and the opportunities this agreement gives both partners to strengthen their activities in improving wheat. This agreement represents another important step for Bayer in achieving its goal to offer innovative solutions from seed to harvest for sustainable cereal production. Undoubtedly, this partnership will result in exciting advances in wheat productivity by both parties that will benefit farmers and the grain trade worldwide."

Monsanto

Wheat requires a "long-term view," according to the company's global wheat research lead, Dr. Claire CaJacob. "We are currently spending more that we are making of wheat technology, but we are looking long term. Different technologies will be rolled out for different wheat classes at different times."

CaJacob says that many of the high throughput genotyping tools it has developed for breeding other crops are being applied to wheat. Monsanto is bringing increased focus to programs such as pathology, varietal purity, expanded di-haploid capacity, and discovery breeding

"WestBred gave us a germplasm base to build from, and now we are collaborating with several universities and providing them access to our tools in exchange for access to their germplasm. Collaboration with universities allows us to fill gaps in our own germplasm base, " said Dr. Kristen Schneider, global wheat breeding lead.

Relationships with key universities are more important in wheat than other crops because farmer investment through their state checkoffs have driven wheat development for a long time. Public research has driven wheat by developing the varieties that area farmers need."

CaJocob said Monsanto believes that collaborating with wheat farmers and universities will allow the company to be successful in wheat. "We work together

with public breeders on traits that are of interest to both of us and that brings value to their university and to Monsanto. In wheat, no one entity can operate alone."

She said that while biotechnology will be important in wheat, it is certainly not the only tool. "Many problems can be solved through breeding rather than biotechnology. When it costs $100-150 million to develop a biotech product, you have to be looking for a broad application across multiple classes.

"Farmers will be seeing wheat varieties that have broader adaptability, spanning across regions and market classes," Schneider said. "Wheat has been a highly segmented crop based on market classes. Now we are making crosses across classes and separating the progeny based on market class. We are breeding all market classes and have a broadly positioned testing network that spans state boundaries."

Bay State Milling

As intermediate processors in the wheat chain, members of the milling industry, such as Bay State Milling Co., are encouraged that collaboration among universities, USDA and private industry is leading to more focus on the functional outputs of wheat in addition to input traits. For example, there is a negative correlation between yield and protein, as protein requires more energy units than starch. Agronomic traits to improve wheat quality with characteristics such as mixing stability and an improved protein profile without causing a yield drag are in development.

"We are starting to operate outside of our own silos," says Michael H. Pate, vice president of research and development, Bay State Milling and a member of the board of directors of the National Wheat Foundation (NWF). "The various groups within the chain are working together better and showing greater sensitivity to each others' needs." As an example, he points to the need for farmers to receive a premium from end users for yield drag that may result from growing a variety with a specific quality characteristic that processors want. He says consumers too may need to pay more for the nutritional demands they make in the form of higher unit prices for certain wheat food products.

Like universities and private technology providers, some milling companies want access to germplasm in order to develop varieties with the quality traits they desire. Many license or purchase germplasm through relationships with seed companies. Bay State Milling is an example of a milling company that possesses its own germplasm. Pate says Bay State believes that whole grain products are the future, and the company is working to develop varieties that make the best whole grain

products. “We’re focused on improved nutrition, wheat that is a more complete protein and more complete meal,” he said.

Collaborating Can Connect the Chain From Farmer to Consumer

“Cooperation among industry experts and throughout the supply chain is essential to ensure we understand the desired products and nutritional qualities demanded by consumers,” says Sears from Syngenta. “We need to get the wheat chain more connected from breeder through consumer before effective marketing and product supply can take place. A breeding program has to straddle the tightrope of both input traits and end-use traits,” Sears said. “If you just breed for yield, all you have is a feed grain instead of a food crop.”

As a food crop, the wheat industry knows it must understand and respond to customer tastes. Colorado Wheat’s Hanavan emphasizes that the Colorado Wheat Research Foundation, which commercializes wheat varieties under the PlainsGold brand, has a close relationship with Ardent Mills and incorporates its specifications into the program.

The end users know that meeting consumer expectations is essential. “We have to be sensitive to nutritional liabilities, such as turning off gluten molecules,” Pate said. Even as well funded NGOs and advocacy groups castigate wheat on a spectrum Pate describes as “ranging from unhealthy all the way to poisonous,” science can respond favorably. According to the National Foundation for Celiac Awareness, an estimated one in 133 Americans, about 1 percent of the population, has celiac disease. “If one of those people is in your family of four and the entire family avoids wheat as a result, now you are talking about four percent,” he says.

An international team of researchers from Arcadia Biosciences; Oregon State University; Washington State University; Northeast Normal University, Changchun, China; and Justus Liebig University, Giessen, Germany, has developed genetically altered wheat seed to prevent the production of gluten in subsequent plants. *(Proceedings of the National Academy of Sciences, 2012)*

The research focused on the enzyme Demeter, which is responsible for activating a group of genes that result in the production of gluten. Using several genetic engineering techniques they managed to suppress the enzyme by 85.6 percent, resulting in a 76.4 percent reduction of gluten in the seeds produced. The research team reported that flour made from the genetically altered seeds appears to be suitable for making bread, and the next level of their work will determine if these grains can be used in foods for people suffering from celiac disease.

Needed: National Momentum Led by Wheat Farmers

Although grown in more regions of the world than any other crop – with nearly a national footprint in the United States – wheat has many more faces and facets than other crops. Wheat's six different classes, each with its unique end use, a body of research that's grounded in the public sector and its predominantly grassroots organizational makeup, the crop does not present as united a policy front or as consistent a story as other commodities. Some would say that the wheat industry's cacophony of voices prevents a strong single voice from being heard.

Primarily a food crop and not a feed crop like corn and soybeans, wheat's future with biotechnology is uniquely complicated by consumer skepticism and misunderstanding about genetic engineering.

"People want so many different things from wheat that it is difficult for the industry to agree on what traits it should bring from the farmers' fields to the end users," says Robert Blair, a Kendrick, Idaho, wheat farmer, member of the Idaho Grain Producers Association and chair of the USWA/National Association.

He points to the irony that although crop breeding started with wheat, most of the scientific advances farmers enjoy today are in other crops, such as corn, rice and soybeans. This indicates the power of private-sector research, particularly biotechnology. "Private companies have the capital investment that research requires. Government support has dropped way back from the gangbuster levels it used to be."

Blair believes that it is farmers' responsibility to inspire the needed public and private investment that wheat deserves. On one extreme, he sees a danger of farmer apathy and, on the other extreme, the overzealous pursuit of grassroots interests that inhibit a national vision for industry growth. "With good farmer leadership, we can tell our story and get the public investment and support we need. When farmers have our story straight and are consistent in identifying our needs and standing behind them together, industry will invest more. Farmers need to see that one person can make a difference, and all of us working together can make a big difference."

He points to the good working relationship between the Idaho Grain Producers Association and the Idaho Wheat Commission that has resulted in significant investment in the state's wheat industry by companies like Limagrain and Monsanto.

Priorities he lists for wheat farmers nationwide to pursue as they prepare for biotech wheat include:

- Low-level presence minimums for biotech crops
- Identity preservation programs for grain handling at elevators
- Leveraging wheat farmers' political influence nationally
- Better communication with all wheat farmers about industry growth initiatives

As public funding for wheat research continues to decline at both national and state levels, public breeding programs, wheat farmer organizations and private companies – technology providers and end-use companies alike – will need to work together to move the industry forward. Wheat farmers have stated their support for new technology – biotechnology as well as sophisticated conventional breeding – in order to increase yields in the fields. Millers and bakers lead the drive for consistent quality characteristics including disease-free wheat, flour yield, uniform kernel size, protein, absorption and mixability. Consumers continue their aggressive demands for safe, nutritious and affordable food of all kinds.

So where will the money come from? Most likely from all parties. Wheat farmers continue to advocate for federal funds, which do return 10:1 on the approximately $11 million that Congress provides the USDA for wheat research, according to the USDA Economic Research Service. Even though the vast majority of wheat varieties planted today are public varieties, no one expects public funds to carry the future load, so universities are being more resourceful in funding their programs through royalties and licensing fees.

Farmers have been helping for years, not just through their advocacy for new technology, but also with their own money. The wheat checkoffs that now exist in 23 of the 44 wheat-producing states generate about $44 million annually. This farmer investment supports university research and development as well as market development for wheat products in the U.S. and around the world. Farmers know state and national organizations will need to help carry the load in advocating for public acceptance and governmental regulatory approvals for forthcoming biotechnology traits.

Private companies are seeing new reasons to increase their investments in wheat research and development, especially when they know there is farmer demand for future seed and crop protection products. Companies also know they need to partner with the public sector and accept non-exclusive arrangements if they are

going to get access to the public germplasm they need to commercialize their own varieties and traits.

Consumers also may have to be willing to pay more for the level of nutrition, assurance of sustainable production and sourcing details on about food ingredients they are demanding.

The NWF has funded ROI studies to analyze the benefits that additional funding could provide to the wheat industry in the areas of domestic and international marketing, public research and consumer education. The studies are investigating how and where significant new funding could come from and how it would help wheat growers and others in the industry.

"This is a bold and necessary step for the wheat industry's future," said NWF President Dusty Tallman, a Brandon, Colo., farmer. "We will use information from the studies to develop the structure that is the most acceptable and practical for the industry without infringing on the authority, funding and priorities of the current state wheat commissions."

Would more farmer investment to national efforts best come from more and increased state checkoffs or a national wheat checkoff help advance the industry? Are there any other options? That's a question the National Wheat Foundation Directors are asking. "We do know that the public-private investment in wheat is far less than other crops. For example, for every $10 spent on corn research (public and private), about 70 cents is invested in wheat," says Jim Palmer, NAWG CEO & NWF Executive Director. "The National Wheat Foundation has just begun a process to evaluate the potential benefits and obstacles of whatever structure is agreeable to states and farmers for additional farmer funding to increase wheat's investments into national efforts. The NWF Directors strong perception is that an expanded national effort will create a much stronger national voice and would support, build and possibly assist in future coordination and proven effectiveness of wheat's state programs. More wheat-producing states could start their own checkoffs, or farmers might consider adding more to what they already checkoff at the state and designate it for national research and development initiatives. Whatever states will control, nominate and direct any national checkoff. When it's been the other way around, there maybe a positive ROI for those commodities, but not nearly the potential that there could and should be." Palmer said.