Wheat Initiative

An international vision for wheat improvement

May 2013

www.wheatinitiative.org

Introduction

Population growth, climate change and unsustainable use of natural resources have already a negative impact on food security in some regions of the world. In the absence of global commitment to build food systems adapted to climate change and ensuring food security while minimizing greenhouse gases emissions and sustaining our natural resource base, this negative impact is likely to increase and lead to global food shortfall and food price rises in the coming decades, resulting in undernourishment and poverty increase in the world's more vulnerable populations. Expanded investments in sustainable agriculture to increase agricultural productivity per land area and to avoid losses in productive capacity, as well as promotion of healthier food diets and food waste reduction, are required to avoid an increasing gap between food supply and demand. Given the time lag between research and development and widespread applications, action is required now, both at national and international levels.

With rice and maize, wheat is essential for human civilization. With more than 215 million hectares planted annually, wheat is the most widely cultivated cereal in the world. It is the most important protein source and provides around 20% of global calories for human consumption. With around 130 million tonnes, annual global wheat trade is higher than that of maize and rice combined. More than 60% of wheat is produced in emerging and developing countries: China and India together produce nearly twice as much wheat as the USA and Russia combined. In North Africa and West and Central Asia, wheat is the dominant staple crop and provides 40 – 50% of all calories. Stable and reliable wheat production and the maintenance of prices at an affordable level are therefore paramount for global food security and political stability.

Among the major staples, wheat is the only crop adapted to low temperatures that can be grown during the cool season, giving it a unique position in many important rotations with rice, cotton, soybean or maize. Farmers cultivating millions of hectares in developing and developed countries have no alternative to wheat as winter crop that can be economically efficient and that simultaneously provides a major dietary component.

While wheat is originally the most cold and drought tolerant crop among the major staple crops, it is unfortunately also the most sensitive to high night and day temperatures. Wheat yield models indicate that a 1°C temperature increase reduces yield potential of wheat by 10% in some parts of the world and that the wheat producers in South Asia and North Africa will be hit hardest by climate change. Experts from the Intergovernmental Panel on Climate Change (IPCC) report that an average temperature increase of 1.5-6°C by the end of this century is likely and the World Bank estimates that we are barrelling down a path to heat up by 4°C if the problem of climate change is not tackled aggressively now. By 2050, scientists project that the world's leading wheat belts: the U.S. and Canadian Midwest, Europe, Northern China, South Asia, Russia, and Australia–could experience, up to every other year, a warmer summer than the warmest one now on record. Wheat yield in 2050 could decline down to 27% compared with 2000 in some regions, reports the International Food Policy Research Institute (IFPRI), unless swift action is taken to limit temperature rise and develop crop varieties that can tolerate a hotter world.

Considering that wheat production needs to be increased by around 60% by 2050 to meet the demand of a growing population with a changing diet, the challenges for wheat breeders and growers are tremendous. Current global investments in wheat improvement are too small to address these challenges properly. The main objective of the Wheat Initiative is therefore to co-ordinate global wheat research efforts so that, through international efforts, the progress needed to increase wheat production, quality and sustainability can be achieved, thus contributing to the global efforts towards food security and safety under changing climate conditions.

Wheat in the world (source FAOSTAT)

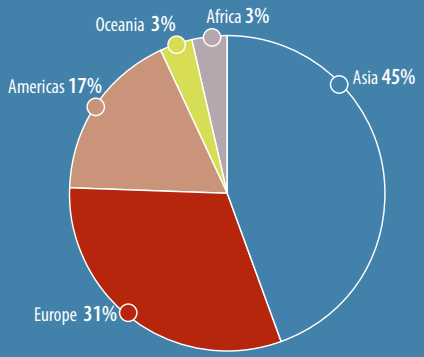
217 million ha planted in 2010,
making wheat the most widely grown crop

144 million tonnes traded in 2010,
more than maize and rice combined

20,4% of total protein supply,
making wheat the most important protein source (data 2009)

18,8% of total energy supply,
wheat being second after rice for calories/capita/day (data 2009)

653 million tonnes produced in 2010,
representing 27% of total cereal production



The Wheat Initiative: vision and mission

The Wheat Initiative [1] aims to encourage and support the development of **a vibrant global wheat public-private research community sharing resources, capabilities, data and ideas to improve wheat land productivity, quality and sustainable production around the world.** This community comprises public and private researchers, educators and growers from all wheat growing countries who together will have sufficient resources and capabilities to develop strong and dynamic national programs on wheat in their country and, at the international level, through transnational collaborative programs. This community will address wheat research globally on all wheat types (bread wheat, durum wheat, and wild relatives), encompassing research fields from genomics to agronomy.

To answer the challenges of wheat research internationally, the Wheat Initiative will:

1• Develop a **global strategic agenda for wheat research** through the identification of research and outreach priorities and challenges beyond the capacity of single research groups/countries, and that can best be achieved by international coordination and collaboration between researchers, research institutions and funding organisations.

2• Encourage **efficient investment in wheat research** based on the capabilities of, and synergies among, national and international programs.

3• Initiate the development of new **collaborative programs and coordinated actions** across developing and developed countries.

4• Develop and coordinate **knowledge sharing** amongst the international wheat community.

5• Improve **access for all to resources, services and facilities.**

6• Support **education of students and life-long learning of wheat researchers and farmers.**

7• Stimulate **public/private partnerships.**

[1] Launched in September 2011, the Wheat Initiative was proposed by research and funding organisations from several countries, and is part of the 2011 action plan of the G20 Agricultural Ministries to contribute to global food security (http://agriculture.gouv.fr/IMG/pdf/2011-06-23_-_Action_Plan_-_VFinale.pdf).

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The Challenge: increasing wheat production, quality and sustainability

With a predicted world population of 9.3 billion in 2050, the demand for wheat is expected to increase by 60% compared with 2010 [2]. To meet this demand, mean annual yield increases must rise from the current level of 1.1% (2001-2010) to 1.6% (2011-2050). A major research effort is needed to increase wheat production and sustainability, while ensuring the production of high quality and safe products, in the face of high food prices, climate change and natural resource depletion.

Wheat today

Since the beginnings of agriculture some 10,000 years ago, cereals have provided the main source of calories for the human diet. Recognised for their high yields, nutritional value, and ease of transport and storage, a range of different cereals were domesticated by the world's original farmers. Wheat, rice, maize, barley, sorghum, millet and root crops constitute the basis of human nutrition worldwide. Of these, wheat has been particularly important, providing the principle grain stock that founded agriculture in the Middle East and led to its successful spread around the world. Today, wheat is grown throughout temperate, Mediterranean-type and sub-tropical parts of both northern and southern hemispheres, and contributes 27% of total cereal production **(Table 1)**. Wheat is:

- **the most widely grown crop worldwide at over 200 million hectares;**
- **the most important protein source and second after rice for food calories.**

[2] Required raise in overall food production estimated to be 70% in 2050 compared with 2005/2007 (FAO), therefore 1045 Mt for wheat. 1045 Mt = 60% increase compared with 2010 global wheat production.

Table 1. Global area, production, yield and contribution to the human diet for major cereal crops

	2010 (FAOSTAT)					2009 (FAOSTAT)			
	Area		Production		Yield	Energy supply		Protein supply	
	M ha	% Total area	M tonnes	% Total production	Tonnes/ha	kcal/ capita/day	% Total energy	g/ capita/day	% Total protein
Wheat	**217**	**32**	**651**	**27**	**3.0**	**532**	**18.8**	**16.2**	**20.4**
Maize	162	24	844	35	5.2	141	5.0	3.4	4.3
Rice	154	23	672	28	4.4	536	18.9	10.1	12.7
Barley	48	7	123	5	2.6	7	0.2	0.2	0.3
Sorghum	41	6	56	2	1.4	32	1.1	1	1.3
Total	683	100	2.432	100	3.6	1248	44	30.9	38.6

Bread wheat represents more than 90% of total wheat production, although durum wheat is prevalent in specific regions. Over the millennia, human selection of wheat plants with superior yield and quality traits has led to significant improvements in cultivated varieties compared to their wild relatives. For example, early selection by the world's first farmers led to the development of varieties that produced grains of larger size that were retained in the ear for longer periods of time. During the 20th century, the introduction of traits for accelerated crop development, semi-dwarf habit, photoperiod insensitivity and enhanced disease resistance, contributed to further dramatic yield improvements **(Table 2)**.

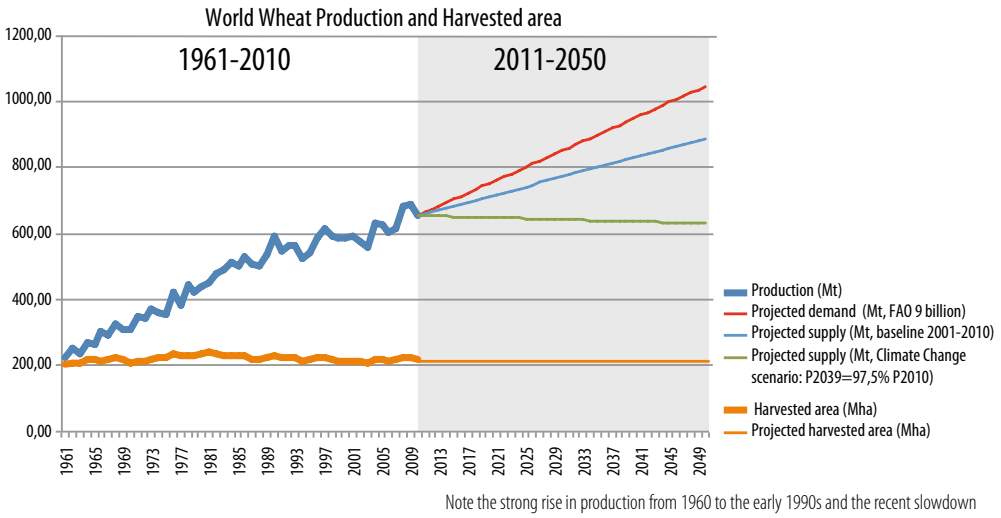
Table 2. Evolution of wheat yield over 10-year periods since 1960 (source FAOSTAT) and projected needs for 2050

Period	Mean area harvested/yr (Mha)	Mean production/yr (Mt)	Mean production increase/yr	Mean Yield (t/ha)	Mean Yield increase/yr
1961-1970	213	278		1.3	
1971-1980	225	388	3.9%	1.7	3.2%
1981-1990	229	509	3.1%	2.2	2.9%
1991-2000	220	571	1.2%	2.6	1.7%
2001-2010	216	622	0.9%	2.9	1.1%
2050 (target)	**220**	**1045**	**1.7%**	**4.75**	**1.6%**

An urgent need to increase global wheat sustainable production

After a strong rise from 1960 during the green revolution to the early 1990's, the rate of increase in wheat production has slowed down **(Table 2, Figure 1)**, with large variations of yield among different countries. With changing diets and growing world populations, rising prices for fertilizers and pesticides, increasing competition between food and non-food uses, and the negative effects of high temperature and drought resulting from climate change, **world wheat production has not met global demand in 10 of the past 15 years** (source USDA). It is estimated that losses due to climate change in some areas of the world will reach 30% by 2050. The volatility and increasing price of wheat is creating havoc in the developing world, where threats to and increasing costs of food supplies are a major source of civil unrest.

Figure 1. Total wheat production and area harvested since 1960 (FAOSTAT 2012) and 2010-2050 projections.



Note the strong rise in production from 1960 to the early 1990s and the recent slowdown

While theoretically more lands could be brought into production, it would alter the long-term sustainability of the global ecosystem. The most direct solution to increase wheat global production is to increase wheat land productivity. However, despite a predicted need for a production increase of 60% by 2050, wheat yield increased globally at only 1.1% *p.a.* during the last decade **(Table 2)** and seems to be stagnating in many regions of the world.

A necessity to increase international coordination and investment

Although specific wheat varieties and/or species adapted to the different production constraints/end products around the world are needed (e.g. spring vs. winter wheat, rain-fed vs. irrigated, bread vs. durum wheat, etc.), all countries share an urgent need to increase the rate of wheat genetic progress for yield, nutrient and water use efficiency, adaptation to biotic and abiotic stress, whilst ensuring the production of high quality and safe products. To take full advantage of the genetic potential, improved agronomic practices and development of innovative cropping systems are paramount. These needs are immediate and will most efficiently and rapidly be addressed by ensuring **coordination and communication among the international wheat scientific community**, establishing common goals, sharing resources and information, enhancing technology delivery to breeders, agronomists, and farmers globally and by improved coordination among public and private research funding organisations.

More efficient use of genetic resources is one of the most important approaches to enhance wheat yield. During the past decade, developments in genomics, molecular genetics and biotechnology have provided new tools for wheat breeding. Together with a better understanding of wheat physiology and development, these **technologies can be used to accelerate traditional breeding programs** or to artificially insert genes into wheat – from related plants or from completely different species. However, a significant and increased investment, both in conventional and molecular-based breeding, is necessary to reduce the time from trait discovery to widespread cultivation of new wheat varieties.

Meeting the growing demand for affordable wheat also requires a new strategic r**esearch emphasis on crop, soil, and water conserving practices that will significantly increase the sustainability of production while accelerating yield gains**. Improvements in water and nutrient-use efficiency are imperative to confront the major trends of declining resources for agriculture, the increasing prices of fossil fuels and the deleterious environmental effects caused by poor fertilizer use practices, including greenhouse gas emissions and ozone damage. At the same time, production methods must lead to reductions in soil erosion and degradation and in decreased use of pesticides and fossil fuels. Achieving the needed improvements in efficiency will require precise and site-specific management techniques that are suited to the needs and capabilities of different types of farmers. These approaches will have to embrace the challenges posed by both seasonal and spatial variability.

In the last 20 years, wheat has become an orphan crop in terms of research investments considering its importance for global food security. As of 2010, global investments in maize research, mostly in the US and Europe, were more than four times greater than in wheat research. To change this situation, **the public and private sectors must address the great challenges facing wheat through substantially increased and coordinated investment in research** [3]. As part of the global response to the major food security challenge over the next 40 years, **international coordination of wheat research is needed to avoid duplication of efforts, increase economic efficiencies, and add value to the existing national or international public and private initiatives**. Coordination is critical to ensure that all countries and groups, particularly in the developing world, have access to technological advances to increase the speed and sophistication of wheat improvement. This effort will ensure that wheat research and improvement programmes are conducted synergistically to increase food security and safety in a changing environment, while taking into account societal demands for sustainable and resilient agricultural production systems.

[3] Recognizing the priority for supporting research aiming at global food security, a number of national or international initiatives with the objective of unravelling and using wheat genetic diversity to breed better wheat varieties, while taking advantage of the fast developing genomics technologies have been launched in the past 2 years. Also, many seed companies have re-evaluated their positions and have begun increasing investments in wheat research and development. Several large national research programmes linking public and private partners were launched recently in France (BREEDWHEAT), the UK (WISP), Canada (CTAG), Italy (AGER) and the US (Triticeae-CAP) adding to existing programs in other countries. At the international level, CIMMYT, along with ICARDA, have presented the CGIAR Research Programme called WHEAT detailing ten strategic research initiatives for wheat improvement and innovative production technologies for the developing world. The Borlaug Global Rust Initiative was also launched a few years ago to coordinate research worldwide to combat the new and devastating stem rust race UG99 and other rust pathogens.

The target: wheat in 2030 and beyond

"Increasing production and productivity in a sustainable basis in economic, social and environmental terms, while considering the diversity of agricultural conditions, is one of the most important challenges that the world faces today" [4] . For wheat, a second Green Revolution is needed to increase global wheat production by 60% by 2050. This will be achieved by breeding high-yielding varieties adapted to diverse environments that are accessible to all, delivering high-quality end products, and cultivated under sustainable crop management practises. Strong and continued investment in both fundamental and applied science will facilitate a more rapid route to significant improvements and will ensure that research is targeted at delivering public goods and improving the economics of farming. Although not of direct relevance to the Wheat Initiative's aims, it will also be necessary to improve infrastructures, develop appropriate regulatory frameworks, improve distribution and access to seeds, as well as developing the whole value chain. Through targeted, coordinated and well-funded actions, we believe that it will be possible to:

Increase the yield potential of wheat cultivars

Increasing wheat production without agricultural expansion implies that we must increase wheat production on existing agricultural lands. This could be achieved partly by improving wheat yield genetic potential through a better understanding of the physiological traits involved and their interactions with the environment, and via their complementary introduction into new varieties by breeding and/or genetic manipulation.

[4] G20 Agriculture vice-ministers/ deputies meeting report, 2012 (http://www.g20.org/en)

Close the yield gaps on under-performing land and increase the sustainability of cropping systems

Due to intensive tillage coupled with indiscriminate use of irrigation water and fertilisers especially nitrogen, soil and water resources have been degraded over time in many locations. Location-specific resource conservation technologies will need to be employed for the long-term sustainability of crop production. While continued improvements in wheat genetics will increase wheat yield potential, better deployment of varieties and improved management will help close the yield gaps seen today in many wheat growing areas and improve end-use quality. Cropping systems for sustainable wheat production, including diversified rotations, will be used in developed and less developed countries and will contribute to the control of pathogens, weeds, and to the reduction of inputs. Knowledge-based decision-making tools and a new generation of precision-agriculture approaches will help farmers decide on the best agronomic practises.

Monitor wheat diseases and develop wheat varieties with durable resistance

An international system will be established to contain the threat of wheat diseases and pests using several approaches, such as the identification of new resistance genes in genetic resources, the wide use of durable resistance genes in breeding programs, the international monitoring of pests and diseases and the appropriate deployment of resistance genes. These approaches will be based on a better comprehension of plant-pathogen interactions.

Increase resource use efficiency and tolerance to abiotic stress

Abiotic stresses such as extreme temperatures, low water availability, high light intensity, high salt, and mineral deficiencies or toxicities can severely reduce yield for wheat and other crops. In many cases, several types of abiotic stress challenge plants simultaneously. High temperatures, high irradiance, scarcity of water and nutrient deficiencies are commonly encountered in environments where wheat is grown but are not amenable to management through traditional farm practices. Integration of genetic and phenotypic data, together with the availability of unique populations adapted to specific environments and end-uses, will improve the understanding of traits determining yield in water and nutrient limited environments. This will allow the creation of wheat varieties with improved nutrient and water efficiencies as well as altered roots to maximise crop nutrient intake and interactions with beneficial soil microorganisms. Advances in the knowledge of symbiotic signalling will allow progress towards Nitrogen-fixing wheat. Conservation agriculture practises will help address temperature fluctuations and moisture scarcity.

Improve the nutritional and processing quality and safety of wheat varieties

Wheat is particularly valued for the functionality of its grain to produce a multitude of end-use products. The suitability of wheat for baked, flat and steamed bread, noodles, pasta, biscuits and cookies is determined by breeding and processing technologies. Evolving processing technologies coupled with changes in consumer preferences demand continual modification of the quality attributes of wheat. Future wheat varieties will exhibit defined functionalities coupled with enhanced nutritional quality through elevated levels of key nutrients such as iron and zinc. The level of harmful mycotoxins produced by fungal diseases in wheat grains will be strongly reduced or non-existent.

Tailor wheat varieties and types to diverse agro-systems and production systems

Merging crop-modelling methods with genomic prediction will bring new levels of efficiency to the identification of genotypes suited to particular climatic conditions, regions and agro-systems. Tailoring phenology and architecture as well as abiotic and biotic tolerance to diverse agro-ecosystems will allow farmers to use varieties well adapted to their growing environment. In

addition to the existing selfed varieties of winter, spring, irrigated, rain-fed durum and bread wheat, new wheat types (e.g. GM, hybrid) and production systems will be available to the growers.

Have all breeders implement modern breeding methods

Well characterised genetic resources from wheat and related species will be accessible to the research and breeding community. Wheat breeders will be aware of the function of many genes, the way they are regulated, and of the availability of genetic variants. Conventional breeding will still be used, but will be complemented on a large scale by approaches already available today such as double haploids (DH), Marker-Assisted Selection (MAS), or transgenics. New breeding methods, under development or emerging, such as targeted mutagenesis, Genome-Wide Selection (GWS) to improve the selection of traits under complex genetic control, or the use of hybrids and/or apomixis to accumulate valuable alleles, will be available for implementation by the breeders. Genetic variability from related species will be widely used to introduce new traits/alleles into wheat by interspecific hybridisation.

Have access to shared platforms and standards

High throughput sequencing and phenotyping as well as statistical genomics and computational efficiencies will revolutionize wheat improvement.

A wheat reference genome sequence anchored to genetic and phenotypic maps will be available to all. The sequence of many accessions will provide a virtually unlimited amount of molecular markers for genetic dissection of important traits and will accelerate isolation of the underlying genes. Genomic platforms using standardised protocols to allow genotyping, transcript and metabolomic profiling for metadata analysis will be available to the community.

Well instrumented phenotyping platforms using common standards and methods will be used to bridge the gap between the identification of gene function and the development of wheat varieties with improved characteristics, by identifying mechanisms and beneficial traits of roots and shoots, by accelerating the breeding process with novel technologies and concepts in controlled, semi-controlled and field conditions and by integrating all these aspects into physiological models.

Benefit from a Wheat Information System providing easy access to data

An integrated Wheat Information System will provide the international wheat research community easy access to existing and future genetic, genomic, phenotypic and agronomic data as well as bioinformatics tools and services to visualize, analyse and connect the different types of data.

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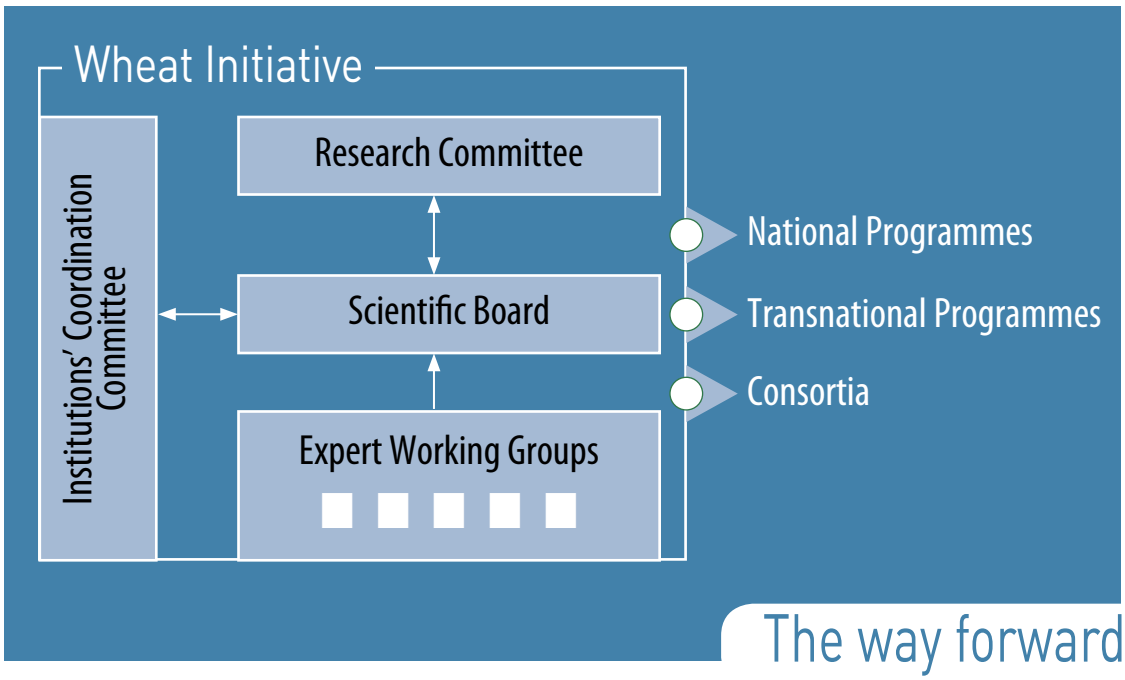

The way forward

The Wheat Initiative will provide a framework to establish strategic research and organisation priorities for wheat research at the international level. It will identify potential synergies and will nurture collaborations between research and development programs for wheat improvement, in developed and developing countries. The Wheat Initiative will also develop specific activities to enhance communication and increase access for all to information, resources and technologies.

Implementation of a Strategic Agenda

An overarching strategy for wheat research and development, with an appropriate balance of short, medium and long-term targets, and with an emphasis on goals necessitating collaboration/coordination at the international level to meet global needs, will be developed and implemented. The priorities will be revised periodically to address new scientific and technological developments.

Investment in research and establishment of international cooperation

Wheat research funders will have the opportunity to work together and address grand challenges, from science to policy to farm to end-users. It is expected that public and private funders will use the Wheat Initiative Strategic Agenda to direct funding in national and transnational research programmes dedicated to wheat priorities, and that it will enable the development of partnerships, joint programmes, and public-private cooperation. Improved knowledge among the funders, added to the opportunity to work together, will enhance efficient and long term funding of wheat research to increase wheat production and food security.

Communication and training

The Wheat Initiative will facilitate communication and training among the wheat community by:

- establishing a biennial International Wheat Congress,
- organising workshops on specific topics relevant to the strategic priorities identified by the Wheat Initiative,
- improving information and communication on wheat research and development activities, initiatives and results across the globe via its website,
- facilitate staff and student exchanges by providing information on training activities.

Access to resources, data, facilities and services

The Wheat Initiative will advocate the importance of the accessibility of genetic and genomic resources of wheat and their relatives and of the creation of a central site for directing seed orders and requests to the appropriate providers.

Common standards and protocols, as well as reference germplasm sets, will be established in the frame of the Wheat Initiative activities to ensure that datasets are comparable over time and space thereby enhancing synergies between programs.

The Wheat Initiative will encourage and facilitate the development of open genomics platforms and the establishment of an international phenotyping network in controlled and field conditions, with services available to the global community. It will also promote the development and sharing of precision-agriculture tools and practises.

The Wheat Initiative will actively support the establishment of an integrated information system providing access to information on genetic resources, genetic and molecular basis of traits, marker-trait associations, genomic sequences, allelic variation at key loci, phenotypic data in different environments etc., through a framework for linking genomic, genetic, phenotypic and agronomic analysis to practical breeding and crop management.

Long-term engagement

The Wheat Initiative governance will be collaborative, transparent, inclusive and engaged. The Research Committee brings together scientists from the public and private sectors and defines priorities for wheat research. Experts Working Groups identify needs and propose strategies in specific areas of research or organisation. The Institutions Coordination Committee comprises high-level representatives from public research/funding organisations who, together, facilitate cross-border collaboration and funding on the priorities identified by the research community. The Scientific Board, elected by the Research Committee, is the executive committee of the Wheat Initiative that translates research priorities into decisions/actions and liaises with the different committees.

The success of the Wheat Initiative will be dependent upon engagement of the global wheat community. It will therefore be of great importance that all countries and companies interested in wheat improvement participate and contribute to the development of this unique international coordination/collaboration platform. Through collaboration, we will improve food security and resolve the urgent challenge of sustainably providing enough safe, nutritious and affordable food for a growing population.

Public and private research organisations
with designated representatives to the Wheat Initiative (April 2013)

Public research and funding organisations


Consejo Nacional de Investigaciones Cientificas y Técnicas (CONICET)


Grains Research and Development Corporation (GRDC)


Agriculture and Agri-Food Canada


Chinese Academy of Agricultural Sciences (CAAS)


National Institute for Agricultural Research (INRA)


Federal Ministry of Food, Agriculture and Consumer Protection


Indian Council of Agricultural Research (ICAR)


Ministero delle politiche Agricole Alimentari e Forestali (MiPAAF)


Japan International Research Center for Agricultural Sciences (JIRCAS)


Instituto Nacional de Investigacion y Technologia Agraria y Alimentaria (INIA)


General Directorate of Agricultural Research and Policy (GDAR)


Biotechnology and Biological Sciences Research Council (BBSRC)


U.S. Department of Agriculture

International Maize and Wheat Improvement Center (CIMMYT)

International Center for Agricultural Research in the Dry Areas (ICARDA)

Private companies

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