

An International Research Initiative for Wheat Improvement

The following research and funding organisations propose this initiative:

Argentina: National Institute for Agricultural Technology (INTA), National Council of Scientific and Technological Research (CONICET)

Australia: Australian Centre for Plant Functional Genomics (ACPGF), Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Canada: University of Saskatchewan, Crop Development Centre

China: Chinese Academy of Agricultural Sciences (CAAS)

France: National Institute for Agricultural Research (INRA), National Research Agency (ANR)

Germany: Leibniz Institute of Plant Genetics and Crop Plant Research (IPK)

Mexico: International Maize and Wheat Improvement Center (CIMMYT)

Turkey: Sabanci University

United Kingdom: Biotechnology and Biological Sciences Research Council (BBSRC)

The initiative is also supported by the International Wheat Sequencing Consortium (IWGSC) and by the U.S. Wheat Genomics Committee.



I. State of the art and current situation

Wheat, rice, maize, sorghum, millet and root crops constitute the predominant basis of human nutrition worldwide and **require a major research effort to increase their productivity and sustainability in the face of high food prices, climate change and natural resource depletion**. Wheat is a major renewable resource for food, feed and industrial raw materials, and among major crops is grown on the largest area worldwide. **G20 members produce 75% of all wheat** and currently wheat is:

- The most widely grown crop worldwide on over 200 million ha;
- The 2nd most abundant staple crop grown worldwide;
- Providing globally 20% of all food calories;
- The most important protein source in developing countries (20%) and 2nd most important food calories source (19%) after rice (FAOSTATS 2009).

2009 Data (FAOSTAT)	Area (x 10 ⁶ ha)	Production (x 10 ⁶ tonnes)	Yield (t/ha)
Wheat	225	682	3.0
Maize	160	817	5.1
Rice	161	679	4.2

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 increased temperature, drought, soil salinization and ozone resulting from climate change, world wheat production has not met demand in 6 of the past 10 years and yet **by 2050 demand will increase by at least 70%**. The volatility and increasing price of wheat is creating havoc in the developing world, where threatened food supplies are a major source of civil unrest. Durum and bread wheat play a key role as a staple in some countries. Annual wheat yield increases must jump from the current level below 1% to at least 1.7% per year to meet demand trends.

In the last 20 years, wheat has become an orphan crop in terms of research investments compared to the most rapidly developing major cereal crop - maize. As of 2010, global investments in maize, mostly in the US and Europe, are more than four times greater than in wheat research. The public and private sectors must address the great challenges facing wheat through substantially increased investment in wheat research. With the application of exciting new technologies, **new varieties and production technologies could raise the economic value of wheat production by 6-25 billion USD/year from 2030 onwards**, based on different scenarios with partial or complete achievement of a 50% wheat yield increase, and calculated at the current wheat price.

A more efficient use of wheat genetic resources is one of the most important goals recognized by G20 member countries for the improvement of wheat productivity. However, a **significantly increased investment both in conventional and molecular-based improvement methods is necessary to increase the response to selection while reducing the time from trait discovery to the release of new wheat varieties**. The availability of a high quality reference sequence of the wheat genome coupled with the development of efficient phenotyping methodologies for field testing will enable new genome-based breeding strategies to **create robust new varieties in 15 years' time**. To fully utilize the benefits from investments in developing new molecular-based breeding technologies, it is paramount that these investments are met by increased funding for conventional breeding.

A number of national and international initiatives aiming at unravelling and harnessing wheat genetic diversity to breed better wheat varieties while taking advantage of the fast-developing

genomics technologies are underway or have been submitted recently to national or international funding public agencies (almost 300 M USD) (see Appendix 1). Also, during the past 2 years, seed industries (Monsanto, Bayer, Pioneer/DuPont, Limagrain, Syngenta, KWS, Dow Agrosiences, Graminor, etc.) re-evaluated their positions and began increasing their 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) and the US (Triticeae-CAP) and Italy (From Seed to Pasta; project on durum wheat). At the international level, CIMMYT, along with ICARDA in the Middle East, have presented a new CGIAR Research Programme called WHEAT¹ detailing 10 crucial strategic research initiatives for improving wheat varieties development and innovative production technologies for the developing world. An International Wheat Genome Sequencing Consortium (IWGSC) was established to coordinate the efforts to obtain a high quality reference sequence of the wheat genome that is needed to pave the way to faster and more effective genomics-assisted breeding and the creation of improved wheat varieties. A European project (TriticeaeGenome) and several other programmes are also underway to generate tools and platforms for molecular breeding.

Meeting the growing demand for affordable wheat also requires a new strategic research emphasis on crop, soil, and water conserving practices that will significantly increase the sustainability of production while accelerating yield gains. Improvements in water productivity and nutrient-use efficiency, especially nitrogen, are imperative to confront the major trends of declining water 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 use of labor, fossil fuel and pesticides. Achieving the needed increments 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.

As part of the global response to the major food security challenge over the next 40 years, **international coordination of wheat research is urgently needed** to avoid duplication of efforts, increase economic efficiencies, and add value to the existing national or international public and private initiatives. Coordination will be 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 will ensure that wheat research and improvement programmes are carried out synergistically to **increase food security, nutritional value and safety in a rapidly changing environment**, while taking into account societal demands for sustainable and resilient agricultural production systems.

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WHEAT is part of a concerted effort of the Consultative Group on International Agricultural Research (CGIAR) to implement a new, results-oriented strategy through a series of CGIAR Research Programmes that exploit the potential of international agricultural research for development to enhance global food security and environmental sustainability. WHEAT draws on the capacities and commitment of two leading international centres (CIMMYT and ICARDA), in partnership with organizations and institutions in the North and South (<http://www.cimmyt.org/en/what-we-do/maize-and-wheat-cgiar-programs>). Building on the input, strength and collaboration of over 200 partners from the public and private sector, WHEAT will catalyze an emergent and highly distributed virtual global wheat innovation network. It will couple discovery science in advanced research institutes with national research and extension programmes in service of the poor in developing countries. Although partly funded, the WHEAT programme will need supplementary investment of up to \$ 60 million dollars per year over the 3 next years.

We therefore propose the creation of an International Wheat Research Coordination Committee to coordinate wheat research programmes at the international level in the framework of an **International Research Initiative for Wheat Improvement**.

II. Added-value of this G20 initiative

One of the objectives of the agricultural G20 is to **increase agricultural production in the long run**. Although several national and international initiatives are underway to improve wheat productivity and quality and its adaptation to global change, there is a high risk that uncoordinated activities will lead to duplication of efforts and waste of time and resources in the race to deliver new wheat varieties meeting global needs. The CGIAR Research Programmes such as WHEAT aims at delivering robust wheat varieties, new resource conserving/precision agronomic practices, and cellphone decision support tools to developing countries. Although specific wheat varieties adapted to the differential production constraints/end products around the world are needed (e.g. spring vs. winter wheat, rainfed vs. irrigated, bread vs. durum wheat, etc.), **all countries share an urgent need to increase the rate of wheat genetic progress for yield, adaptation to biotic and abiotic stress, and nutrient use efficiency. To take full advantage of genetic potential, improved agronomic practises and development of innovative cropping systems will also be a top priority.** These needs are immediate, and would most efficiently and rapidly be addressed by bringing transparency and coordination to **the international wheat scientific community, sharing resources and information, establishing common goals, enhancing technology delivery to breeders and farmers globally and by improved coordination among research funding organisations.**

III. Objectives of the project and results expected

The key role of the International Research Initiative for Wheat Improvement will be to add value to existing wheat research capabilities and activities through building and strengthening collaboration, coordination of research and support in accessing research outcomes. Although this initiative does not represent a new research organisation, it will provide a mechanism to support and nurture organisations that undertake research in wheat improvement and help to build new initiatives in research and technology delivery.

The main objectives of the International Research Initiative for Wheat Improvement, coordinated by the International Wheat Research Coordination Committee, will be to:

- Coordinate world-wide wheat improvement research efforts;
- Provide a forum to identify synergies and encourage collaborations among major nationally and internationally (public and private) funded wheat programmes with the result of maximising opportunities for gaining added-value internationally;
- Establish and periodically update priorities for wheat research of global relevance;
- Facilitate and ensure open communication and free, unencumbered exchange of germplasm, data, materials and ideas within the wheat research community;
- Recommend minimum data-reporting standards and develop protocols to allow consistency for screening and analyses;
- Support the development of publically available integrated databases and platforms;
- Monitor and summarize progress of scientific activities;
- Communicate to national and international funding agencies the needs of the wheat research community of participating nations.

The first aims of the International Wheat Research Coordination Committee will be targeted towards generating and sharing the broad range of available tools, methods and results that will enable breeders to take full advantage of genomics-assisted approaches and agronomists to implement resource conserving/precision agriculture worldwide.

This will promote rapid sharing of information and knowledge by avoiding technical barriers and promoting rapid translation and adoption of research results to deliver improved wheat varieties and more efficient agronomic practices. The first expected deliverables are:

- A dynamic information system for the research community to access all publicly available data (phenotypes, genome sequence, various -omics datasets, genetic and physical maps, genetic resources, bioinformatic tools, etc.);
- In the frame of the IWGSC, a publicly available, high quality, annotated sequence of the wheat genome;
- Common genotyping tools (in the frame of the International Wheat SNP Working Group, IWSWG) and reference genotypes;
- Phenotyping networks open to the international community to maximise the dissemination of knowledge across different countries and environmental conditions;
- Characterization of wheat genetic resources and facilitation of their exchange;
- Minimum standards for reporting data and results to facilitate the comparison of data produced in different countries, environments, management systems and research projects (genotyping, phenotyping, various -omics datasets, soils, agronomic practices, etc.);
- A compendium of rigorous and accepted methodologies for the collection of agronomic and environmental data;
- A standardized and user-friendly database structure for archiving agronomic data that will allow data mining by the global research community as well as time-bound data protection.

These first actions will support the undergoing revolution in genomics-assisted breeding, resource conserving/precision agronomic technologies and deliver new improved wheat genetic material and agronomic practices in the next 10 years that will be available to breeders worldwide to produce new high-yielding varieties adapted to different environments and characterized by a higher yield stability and better nutritional quality.

IV. Actions to be developed

1. Set up of the International Research Initiative for Wheat Improvement

- **Presentation to the wheat scientific community**

The International Research Initiative for Wheat Improvement will be presented to the wheat scientific community during two international conferences, the 2011 Plant GEM Conference (Istanbul, May 4-7) and the 2011 ITMI Workshop (Mexico, September 5-9), to ensure input and support from the international community.

- **Interactions with the CEOs of major G20 research organisations**

Interactions with the CEOs of the G20 research organisations working on wheat will be organised through e-mail and video-conferences to develop a common vision and agenda.

2. Launch of the International Research Initiative for Wheat Improvement

A **high level meeting** bringing together international wheat scientific leaders, CEOs of major G20 and international research organisations and representatives of the G20 member states will be organised in Paris, France on the 14th of September 2011 to officially launch the International Wheat Initiative.

3. Development of the International Research Initiative for Wheat Improvement

- **Nomination of the International Wheat Research Coordination Committee and appointment of chairs and deputy chairs**

The International Research Initiative for Wheat Improvement will be set initially under the aegis of the International Triticeae Mapping Initiative (ITMI) for genomics/breeding and under the CGIAR WHEAT for agronomic practices. The scope of ITMI has broadened since its creation in 1989 to cover most aspects of wheat and barley genetic and genomic research. Other working groups will be organised as needed by the International Wheat Research Coordination Committee. The working groups will meet separately once a year and will be composed of representatives from major public research programmes, international research organisations, and private companies. Chair and Co-Chairs for each working group will be identified among the representatives and will meet jointly once each year for broad strategic planning. They will coordinate specific tasks and track progress towards the goals outlined in the Strategic Plan of the International Research Initiative for Wheat Improvement.

INRA (France), BBSRC (UK) and CIMMYT will support financially the coordination activities of the International Wheat Research Coordination Committee during the first 4 years of the project.

- **Development of a common vision and of a strategic plan for the International Research Initiative for Wheat Improvement**

A vision paper and strategic plan will be written by the International Wheat Research Coordination Committee to develop a common research agenda and define the first actions to be undertaken. The vision paper and strategic plan will be submitted for endorsement to national and international research organisations and distributed to funding agencies. It will be used as a reference document to set the goals for wheat research and promote them at the national and international level. These goals will be revised periodically to take into account new scientific developments. It is expected that the G20 member states authorities and funding agencies will use the plan to support and fund national and international research programmes dedicated to wheat research.

- **A centralised information system**

Several databases containing information on wheat already exist. Nevertheless, none are comprehensive, and there is a need for a centralised information system providing the wheat research community with:

- A web portal dedicated exclusively to wheat, comprising an access to databases as well as to bioinformatics and statistical tools, a description of ongoing research projects and initiatives, news and job opportunities;
- User-friendly information system(s)² for the storage and visualisation of genomic, genetic, phenotypic and agronomic data, containing information on genetic resources, and providing tools to connect different types of data;
- A simple means for directing orders and requests for information or materials to the appropriate provider;
- A central repository of protocols and methods recommended for wheat genotypic and phenotypic analysis and agronomic data acquisition, contact details for support;
- A discussion forum for the wheat scientific community.

² The feasibility and utility of a common database for the genomic, genetic and phenotypic data and the agronomic data will be assessed, and the structure of one or both systems defined.

A top priority for the Initiative will be to secure sufficient funds and personnel necessary for the day-to-day management and the upgrade of such an information system for a period of at least 10 years. One of the first actions of the International Wheat Research Coordination Committee will be to undertake a scoping study to determine the best platform for the centralised information system. It may be possible to build on existing wheat databases or to modify an existing system developed for other crop species. INRA and BBSRC will collaborate and consult with leading G20 researchers on the provision of bio-informatics facilities and associated support staff to host and manage a wheat centralised information system.

- **A publicly available high quality reference sequence of the wheat genome**

The complete wheat sequence will usher in a new era of wheat improvement through breeding. International efforts coordinated by the IWGSC are ongoing to achieve the “tour de force” of producing a high quality reference sequence of the wheat genome and allow us to crack the wheat genetic code. The IWGSC is committed to ensuring that the wheat sequence is publicly available to all. Although several countries have already committed resources to the international wheat sequencing project, further significant financial investment³ will be needed to secure the public release of the wheat reference genome sequence in 2015. Various groups are working towards securing this commitment and the International Wheat Research Coordination Committee will work to support these activities.

- **A framework for linking genome and genetic analysis to practical breeding.**

Genetic analysis in wheat has developed dramatically in recent years. New genomics resources, improvements in phenotyping, and genetic analysis have led to the identification of genes and genetic regions controlling many traits of importance to wheat breeding. With the availability of a reference sequence, the rate of gene identification and characterisation will accelerate. High-throughput genotyping is a powerful tool for creating integrated physical and genetic maps, cloning genes of agronomic importance, detecting useful marker-trait associations and devising efficient breeding strategies for wheat improvement. The new resources and capabilities offer major advances in the speed and sophistication of wheat breeding and the evaluation of genetic resources, including untapped genetic stocks stored in international gene banks around the world. An important role of the International Research Initiative for Wheat Improvement will be cataloguing marker trait association, collating information on allelic variation at key loci, and providing information on sources of key germplasm and on germplasm suitable for use in breeding. The Initiative will also work to link international groups so that breeders, particularly those in developing countries, can access training, materials, and resources from the appropriate groups.

- **An international network of phenotyping platforms**

Several research organisations have developed or are establishing high-throughput phenotyping platforms in controlled conditions and in the field. Access to these platforms at the international level will allow the assessment of wheat genetic material for adaptation to different environments. Sharing the phenotyping tools and methods and setting standards will be necessary to ensure that datasets are comparable over space and time.

- **A biennial International Wheat Conference**

International Wheat Conferences and International Wheat Genetics Symposia are organised every 4-5 years. The International Wheat Research Coordination Committee will endeavour to link these two initiatives and organize every other year an international conference bringing together scientists involved in wheat research, to share the latest results in the different fields of wheat research, to create or sustain links between the research groups and help setting up international collaborations. The conferences will be self-funded through the registration fees

³ \$50 millions will be needed to achieve the reference sequence of the wheat genome.

and with the financial support from sponsors. Travelling and registration grants will be allocated to early career scientists, especially those from developing countries.

V. Schedule

Deliverable	Description of the deliverable	Delivery date
Coordination actions		
1	Presentation of the International Research Initiative for Wheat Improvement to wheat scientists	05 and 09/2011
2	Interactions with CEOs of research and funding organisations	05-06/2011
3	Launch of the International Research Initiative for Wheat Improvement and nomination of chair and co-chairs of the International Wheat Coordination Committee, appointment of coordinators for genomics/breeding and agronomic practices	09/2011
4	Vision paper and strategic plan of the International Research Initiative for Wheat Improvement	01/2012
5	Scoping study to determine the best platform(s) for the centralised wheat information system	01/2012
6	Opening of web portal, discussion forum and Wheat Information System	02/2012
7	First International Wheat Conference organised by the International Wheat Research Coordination Committee	2013

Appendix 1: Major wheat public initiatives – genetics and crop improvement

	Country	Coordinating research organisation	Budget	Duration	Title	Main target
Physical mapping and sequencing	France	INRA (3 partners)	8.2 M USD	2010-2013	3B-Seq*	Chromosome 3B sequence
	UK	BBSRC -The Genome Analysis Centre (4 partners)	8,8 M USD (pending)	2011-2016	Wheat Genomics for Global Food Security*	Chromosomes 2B, 4B, 2D physical maps & draft sequences, sequencing technologies
	US	Kansas State University (3 partners)	2 M USD	2006-2011	Integrated Genetic & Physical Map of Chromosome 3A	Chromosome 3A physical mapping and survey sequencing
	US	University of California, Davis (3 partners)	6.8 M USD	2008-2011	Physical Mapping of the Wheat D-Genome*	Chromosomes 1D, 4D, & 6D physical mapping, <i>Ae. tauschii</i> physical map
	Czech Republic	Institute of Experimental Botany	~0.5 M USD (estimate)	2009-2012	7DS Physical Map	Chromosome 7DS physical mapping, gene cloning
	Czech Republic	Institute of Experimental Botany	2.4 M USD (pending)	2011-2016	Sequencing chromosomes 4A, 3DS, 7DS*	Chromosome 4A, 3DS and 7DS draft sequence
	Germany	IPK-Gatersleben	1.4 M USD	2011-2012	TRITEX*	Chromosome 6A physical mapping, improve barley physical map, and develop rye virtual gene order
	Argentina	CONICET and INTA	0.5 M USD (estimate)	2011-2015	4D Survey Sequencing*	Chromosome 4D survey sequencing and marker development
	Italy	CRA Genomic Research Centre (4 partners)	2.5 M USD	2008-2011	Physical Mapping of Wheat Chromosome 5A *	Chromosome 5A physical mapping and survey sequencing
	Turkey	Sabancı University	0.4 M USD	2011-2013	Physical Mapping of Wheat Chromosome 5D*	Chromosome 5D physical mapping and survey sequencing
	Japan	NIAS (4 partners)	0.5 M USD (estimate)	2010-2012	6B Physical Map*	Chromosome 6B physical mapping and survey sequencing
	Japan	NIAS (5 partners)	10.5 M USD	2011-2012	6B Physical Map and Reference Sequence*	BAC-based physical map and sequence of chromosome 6B, transcriptome resources and markers.
	Russia	Institute of Cytology & Genetics (3 partners)	0.5 M USD	2010-2012	INRA-RFBR *	Chromosome 5B physical mapping and survey sequencing, gene cloning,
	China	Northwest A&F University (2 partners)	0.8 M USD		Construction of Physical Map for Wheat Chromosome 7DL*	Chromosome 7DL physical mapping, gene discovery, marker development
India	Punjab Agricultural University (3 partners)	7.9 M USD	2011-2014	Physical Mapping & Draft Sequencing of Chromosome 2A*	Chromosome 2A physical map & draft sequence, gene discovery, map-based cloning	

* : project under the aegis of the International Wheat Sequencing Consortium

	Country	Coordinating research organisation	Budget	Duration	Title	Main target
Physical mapping, sequencing, marker development, molecular breeding	Australia	University of Murdoch/ACPF/CSIRO/Bioplatforms Australia	8.1 M USD	2010-2013	7A Physical Map*	Chromosome 7A physical mapping, survey sequencing, marker development, SNP discovery, molecular breeding
	EU	INRA (16 partners)	9.6 M USD	2008-2012	TriticeaeGenome*	Physical mapping, map based cloning, molecular breeding in wheat and barley
	Canada	University of Saskatchewan (9 partners)	9.4 M USD	2011-2014	Canadian <i>Triticum</i> Advancement through genomics (CTAG)*	Chromosome 6D reference sequencing, genotyping, marker development, SNP discovery, molecular breeding
	France	INRA (26 partners)	48,2 M USD	2011-2020	Breedwheat*	Chromosome 1B sequence, Genomics assisted breeding
	Norway	UMB (4 partners)	1.8 M USD (estimate)	2010-2013	Expanding the technology base for Norwegian wheat breeding: Sequencing wheat chromosome 7B*	Chromosome 7B physical mapping and reference sequencing, gene discovery, marker development, map-based cloning, molecular breeding
Marker development and gene discovery	US	Kansas State University	0.45 M USD	2009-2012	SNP discovery and International wheat SNP working group *	Illumina Infinium chip development
	UK	University of Bristol (3 partners)	1.6 M USD	2009-2011	Mining the allohexaploid wheat genome for useful sequence polymorphisms*	Survey sequencing, SNP discovery
	US	Cold Spring Harbor Lab (NSF)	3.5 M USD		Gene discovery	Gene discovery in wheat and progenitors

* : project under the aegis of the International Wheat Sequencing Consortium

	Country	Coordinating research organisation	Budget	Duration	Title	Main target
Wheat improvement	Australia	ACPFPG	81 M USD	2003-2012	Australian Centre for Plant Functional Genomics	Wheat and barley abiotic stress tolerance
	US	Kansas State University	2.5 M USD	2009-2013	Wheat trait discovery pipeline	Development of pipeline for mapping, functional analysis and deployment of useful agronomic traits
	US	Cornell University, USA (20 main partners)	40 M USD	2011-2016	Durable Rust Resistance in Wheat	Identify new stem rust resistant genes in wheat, improve surveillance, and multiply and distribute rust-resistant wheat seed to farmers and their families.
	US	UC Davis + 53 partners	25 M USD	2011-2016	Triticeae-CAP	Genomic-assisted breeding (wheat and barley)
	UK	BBSRC – 6 partners	28 M USD	2011-2017	Wheat Improvement Strategic Programme (WISP)	Wheat pre-breeding
	UK	BBSRC Institute / University partners	15 M USD	2009 - 2012	Wheat Improvement	Various competitive strategic programmes
	Argentina	FONCYT	0.5 M USD	2008-2011	Biotechnological tools to increase sustainability and competitiveness in the wheat chain (PAE 37108)	marker development and molecular breeding, pre-breeding
	Argentina	INTA	0.4 M USD	2009-2012	Development of adapted germplasm with tolerance against biotic and abiotic stress	QTL mapping and marker assisted breeding, pre-breeding
	Mexico	ICAR, CAAS and CIMMYT	3 M USD	2010-2013	Generation Challenge Programme wheat research initiative	Molecular Breeding for wheat drought tolerance in China and India
	Mexico	CIMMYT, Mexico + 25 partners	35 M USD (need 50 M USD for complete funding)	2011-2020	Seed	Mine the global genetic resources of wheat in search of alleles in improve food security, adapt wheat for climate change and mitigate the effects of resource limitation
	Mexico	CIMMYT + 12 partners	7 M USD	2011-2017	Wheat Yield Consortium	Wheat breeding to increase yield potential
	Australia	CSIRO	12 M USD	Annual budget	Strategic wheat improvement using conventional and molecular approaches	Wheat pre-breeding for yield, abiotic and biotic stress and grain quality
Australia	CSIRO	15 M USD	Annual budget	Dryland wheat production	Wheat Systems research	