The International Wheat Yield Partnership

Strategic Plan 2017-2022

THE INTERNATIONAL WHEAT YIELD PARTNERSHIP (IWYP)

IWYP is a unique partnership of public and private institutions that deploys a new and highly efficient model for funding international research, and coordinating and integrating the research into a holistic science and development program. It seeks to assist in ensuring global food and nutritional security in the future when world population soars and outstrips our current ability to produce the amount of food required. The IWYP model is purposely different, our goals ambitious and our stakeholders focused on delivery with a sense of urgency. To achieve these globally vital goals, more partners, more and better aligned investment, and continued commitment of all involved are required in this and related initiatives.

Summary of Strategic Goals for the Next 5 Years

IWYP Goal

To increase the genetic yield potential of wheat by 50% by 2035

- ✓ Deliver first higher yielding germplasm
- ✓ Bring in additional top quality science
- ✓ Achieve a succession of research breakthroughs in key traits
- ✓ Create added value by combining breakthroughs in elite germplasm
- ✓ Move improved germplasm into breeding programs around the world
- ✓ Coordinate projects around the world for greater efficiency
- ✓ Raise another US$50 million to help bring successions of breakthroughs into world breeding programs

BACKGROUND

The Global Need

As the world population continues to grow rapidly, the fact that much more food needs to be grown on essentially the same amounts of land is well established and accepted. This is compounded by changing diets, changing climates, and pests and diseases that will continue to undermine sustainably high crop production which will put even more stress on food supplies and their cost to consumers. Without higher yielding and more climate resilient crop varieties, agronomy and sustainable inputs, the world is on a course for catastrophes in food and nutritional security with all the associated social and political implications.

Wheat in the World

Globally, wheat is the most important food staple crop providing about 20% of daily calories and protein and is currently grown on approximately 230 million hectares. It is estimated that by 2050 there will be more than 9 billion people on earth, thus wheat demand is expected to increase by 70%. The annual rate of increase of global grain yield per hectare has dropped considerably since the Green Revolution in the 1960s-80's and so research breakthroughs in breeding and agronomy are critical to elevate improvements to the levels required. This is nearly double the current year-on year rate. Closing yield gaps by controlling pests and diseases, by improving soil health and by increasing water and nutrient use efficiency will help considerably but the basic genetic yield potential coming from the design of the crop and its physiological systems needs to be significantly optimized. Importantly, given the lengthy time necessary for research, development, evaluation and deployment of substantially improved crops (from research to "farmer-ready cultivars" takes about 15 years), the world is already late in a concerted effort to find the required breakthroughs.

Whilst wheat is a staple source for calories and protein for vast numbers of people across the globe, it is not a crop that is especially profitable for most private breeding companies in large industrialized countries to

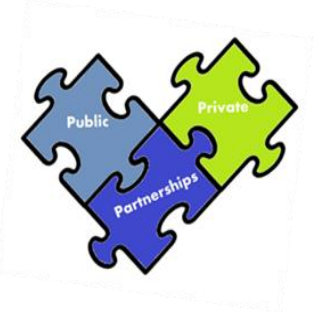
improve and market. The very advantage it has for farmers—the ease of saving seed for next year's crop—equates to a reduced revenue and therefore less of a business incentive for companies to invest in breeding for product development. Further, due to the complexity of its genetic makeup, it is difficult, time consuming and therefore costly to breed for improvements. This is in sharp contrast with hybrid maize and most other significant staple crops. These circumstances demand new systems for improving wheat in order to sustain current and future needs. Currently, the Consultative Group for International Agricultural Research (CGIAR), with public funds from government donors, finances wheat breeding for developing countries in liaison with national breeding organizations. Alternatively, private breeders focus on more industrialized and resource rich societies where farmers seek improved, high yielding seeds and mostly choose to buy them new each year.

The International Wheat Yield Partnership (IWYP) and the Wheat Initiative

In November 2012, funding agencies and organizations from the G20 countries agreed to work together towards global food and nutritional security and formed the global Wheat Initiative (http://www.wheatinitiative.org/) in order to develop an international strategic approach to support research that would lead to step-change increases in the productivity of wheat. An essential pillar of this strategy is to dramatically increase the genetic yield potential of wheat, by up to 50% in the next 20 years. To accomplish this goal, several national agricultural research funding agencies recognized that a new model for collaborative funding could be beneficial to address the special conditions of wheat. This model could be structured in such a way that the public sector could help the private sector, and vice versa, and benefit by the combined resources and effort. The result is the International Wheat Yield Partnership, or IWYP, where Members of the Partnership come from both the public and private sectors. It is a not-for-profit voluntary collaborative partnership focused on one of the most important Grand Challenges of the century. The public sector contributes high quality research seeking breakthroughs to boost wheat yields around the world and the private and public sectors across the world exploit the validated discoveries for breeding, testing and marketing better varieties for their respective markets. There is no significant duplication in public and private sectors because the environments and national markets for which their respective products are optimized are significantly different, and therefore all the locations where farmers grow wheat can benefit. IWYP exploits the best relevant science globally, is focused, operates with a sense of urgency, leverages outputs to generate added value and drives research outputs to delivery to both public and private applied wheat breeding programs worldwide, with the ultimate goal of generating significant yield improvements in farmer's fields. It also takes many steps to make sure its efforts are aligned with other current relevant research programs worldwide. IWYP policies also ensure that the global exploitation of discoveries is not undermined by intellectual property constraints.

In order to serve the global needs for wheat research and development and delivery of higher yielding varieties to ensure food and nutritional security in the future, coordination of expertise and resource contributions from both the public and private sectors is necessary. Importantly, the global production of wheat not only depends on the inherent genetic yield potential but also on many traits for tolerance to biotic and abiotic stresses, as well as efficient and effective agronomic practices to realize yield potential. This is the where the alignment and connections of IWYP to other wheat research and breeding programs is essential.

Leadership and Management of the Partnership



The top level IWYP Science and Impact Executive Board (SIEB) is composed of senior representatives of major national funding agency investors and international research organizations who are experienced with wheat science and the wheat industry worldwide. This currently includes the Biotechnology and Biological Sciences Research Council of the United Kingdom (BBSRC), Grains Research and Development Corporation of Australia (GRDC), United States Agency for International Development (USAID), United States Department of Agriculture's Agricultural Research Service (USDA ARS) and National Institute of Food and Agriculture (USDA NIFA), Department of Biotechnology of India (DBT), International Maize and Wheat Improvement Center, in

Spanish, Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), Agriculture and Agri-Food Canada (AAFC), Institut National de la Recherche Agronomique of France (INRA), Syngenta Foundation for Sustainable Agriculture (SFSA), Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food of Mexico (SAGARPA), the Consultative Group for International Agriculture (CGIAR) and the Wheat Initiative. The IWYP SIEB also includes some representatives from the major international biotechnology and seed breeding companies who have significant research and development capabilities and operate in multinational markets. Private industry partners currently include Syngenta, Bayer, Pioneer, KWS, Limagrain, Mahyco, RAGT, LongReach and SeedCo. Operationally, the Science Program is coordinated by an independent management team consisting of a board chair, program director and secretariat.

IWYP's Strategic Goals and Outcomes are Shared Between the Public and Private Sectors

Wheat improvement is a lengthy process, comprised of many stages, from discovery research through to release and production of improved cultivars, and can take more than a decade to complete (see figure below). Both the public and private sectors are involved in many of these steps from concept to application in many ways, but predominantly, public researchers excel in the discovery, research and validation phases whereas private industry is expert at taking validated discoveries into breeding programs, testing the new lines for commercial relevance, developing them into putative varieties, large scale trialing for performance, multiplying seeds and delivering new improved varieties to farmers. In the developed world with large farms and intensive production practices, private industry has the major role in development and delivery to famers. In the developing areas of the world, breeding, trialing, multiplication, and delivery of new varieties is largely served by the public sector.

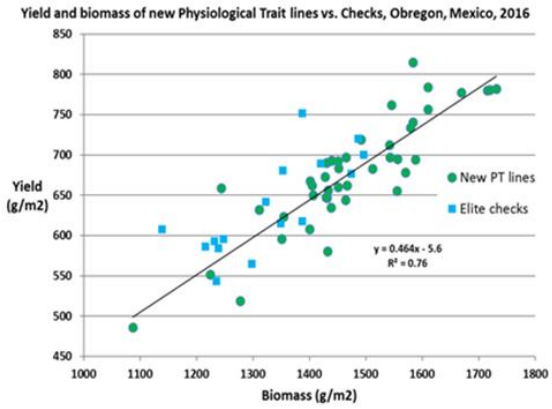
However, in many parts of the world, whether developed or developing, many of these processes are carried out in both public and private sectors as shown in the diagram below.

THE IWYP SCIENCE PROGRAM

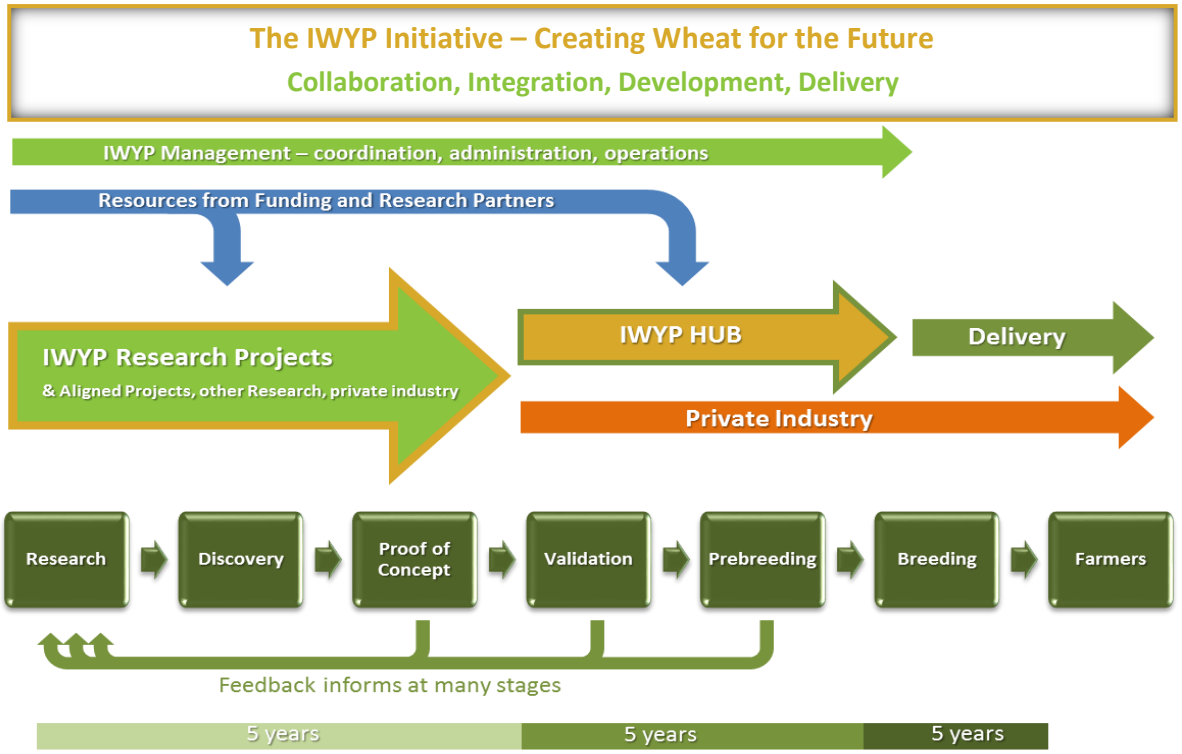
Scientific Strategy

IWYP's research priorities are to discover the traits and their underpinning genetics in order to build higher performing wheat plants for as many parts of the world as possible. These improved wheat plants will have increased biomass, an ideal architecture and growth rate that overall captures more sunlight; converts, uses and distributes the captured energy more efficiently; utilizes more of this energy to produce more and larger grains; and overall results in a new type of wheat plant with transformative levels of yield and productivity.

Adoption of this strategy followed a comprehensive analysis from leading experts of what limits the potential yields of wheat varieties around the world, separate from pests, diseases, nitrogen fertilizers and poor soils. It was concluded that for spring wheats the rapid generation of the canopy followed by improved efficiency of grain production were key for increasing yield. They concluded that photosynthetic rates were below those theoretically possible so discovering ways to increase photosynthesis leading to a more rapidly growing plant of higher biomass before flowering was a primary target. Also, ways of increasing carbon transfer into larger numbers of developing grains was another key target. These are the scientific backbones of IWYP's strategy.



Overall, the IWYP strategy is built upon the willingness of leading research scientists and their institutions around the world, with support from national funding agencies, to focus on the challenges associated with increasing the genetic yield potential of wheat and to make their results freely available for downstream development. The scientists respond to competitive Calls for research proposals, defined by IWYP and aligned funding agencies, and after international expert peer review the selected scientists and their institutions become stakeholders in part of IWYP's integrated strategy (the IWYP Science Program) and contributors to IWYP's research and development pipelines. They form the essential driving force for making the new discoveries that IWYP can turn into breakthroughs in wheat yield potential.



The discovery teams produce proof of concept and then the discoveries are validated in field trials in the world-class evaluation systems of CIMMYT in Mexico (the IWYP Hub, see below) and / or other similar systems. Those discoveries that look promising are then combined with others into elite germplasm in the IWYP Hub prebreeding pipeline at CIMMYT or in parallel in the private sector. Following assembly into elite lines, the new germplasm then enters into varietal based breeding programs, both public and private, to select the best lines with the full range of traits required for the different wheat production environments around the world. This scheme is outlined in the Figure below.

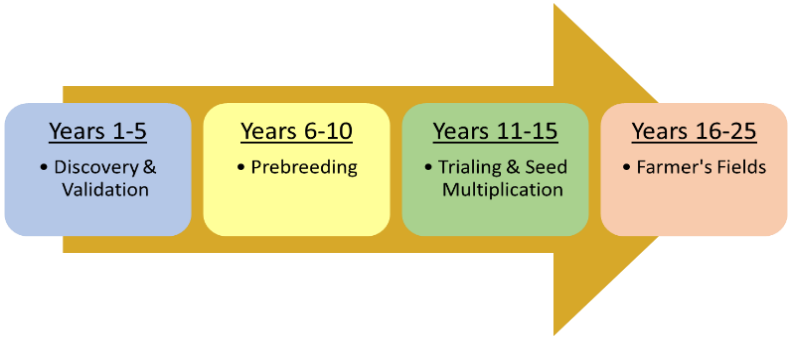
The IWYP strategy enables new scientific developments to enter the pipeline from anywhere in the world at regular intervals. It results in waves of successive improvements coming out of the pipelines to achieve a higher rate of yield gain. It enables breakthroughs to be combined with one another rapidly to seek greater enhancements and add value.

Translating Research and Delivering the Discoveries through the IWYP Hub

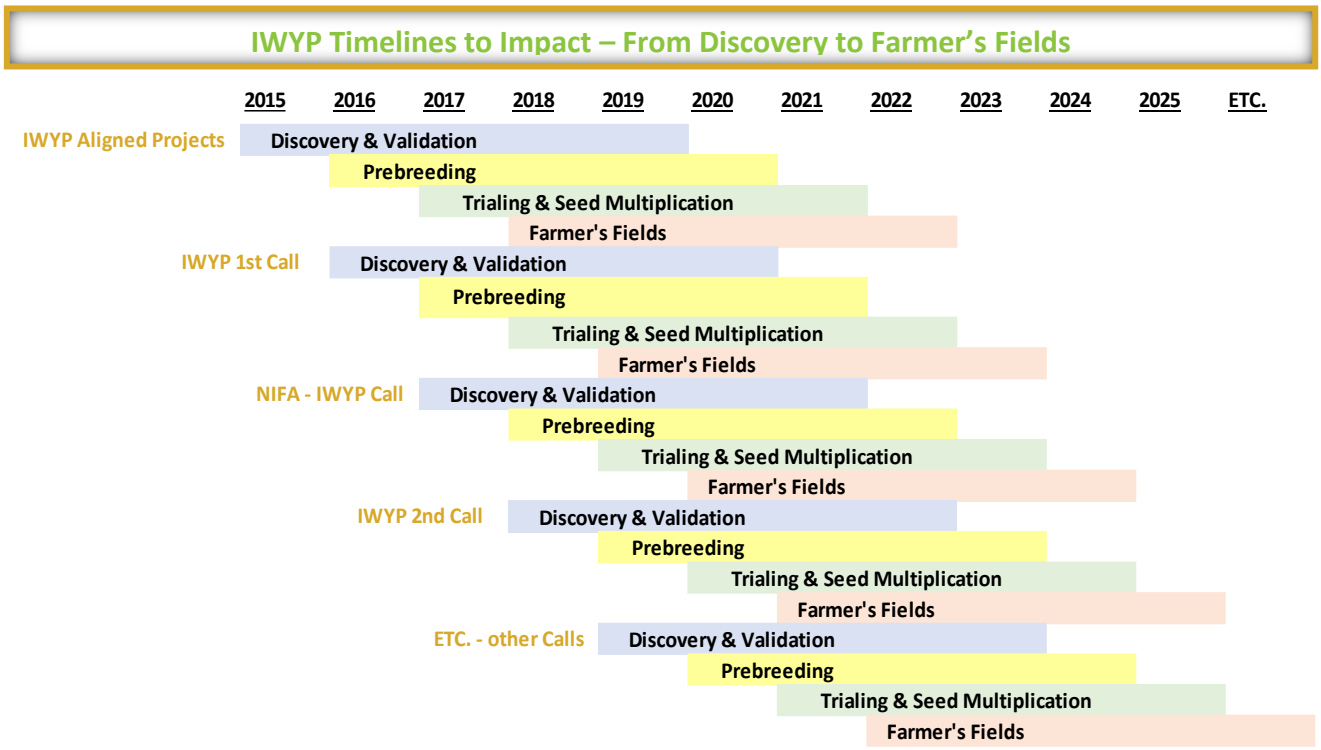
A distinctive feature of the IWYP initiative is a centralized validation and development platform called the "IWYP Hub", in partnership with CIMMYT in Mexico that enables and ensures that its research outputs are developed and delivered to breeding programs worldwide to create impact. The IWYP Hub at CIMMYT has a critical mass of scientists expert in genetics, genomics, physiology, breeding and remote sensing as well as state-of-the-art facilities and a high throughput precision phenotyping platform. Field evaluations are conducted in conditions simulating multiple environments relevant to a large portion of wheat production climates across the world. At the IWYP Hub, research outputs from individual IWYP research projects across the world are validated, compared side-by-side and translated through prebreeding into elite lines for delivery to breeding programs. The IWYP Hub further provides the opportunity to discover synergies between genes and traits and therefore generate added value in terms of gains in yield beyond what was originally envisaged in the individual research projects. New elite germplasm from the IWYP Hub is evaluated at the Hub and then in international trials and delivered to breeding programs worldwide via CIMMT's International Wheat Improvement Network (IWIN). In summary, the IWYP Hub enables IWYP to drive its research discoveries / traits / germplasm toward the market and into farmer's fields.

TIMELINES FOR IMPACT

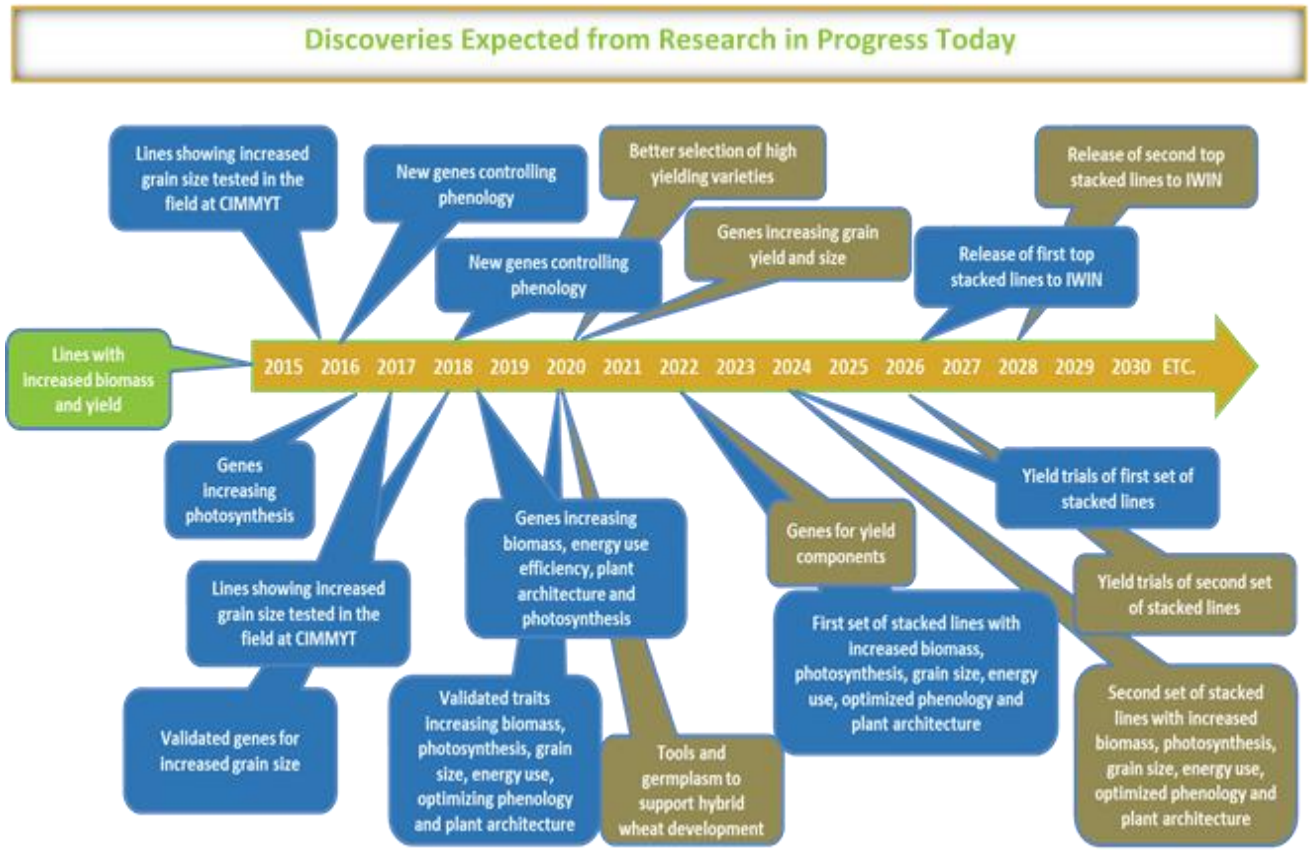
Projected Rounds of Discovery, Breeding, Evaluation and Seed Multiplication



The research, development and delivery of discoveries from the lab to farmer's fields is a lengthy process, typically taking some 10-15 years before impact begins to be realized. Further, as IWYP is seeking breakthroughs in yield potential via novel and high risk ideas, it is naïve to think that IWYP can achieve its goals and objectives via a single round of research projects. Therefore, multiple rounds of research are being initiated followed by multiple rounds of development, prebreeding, trialing, seed multiplication and delivery of new improved varieties. This is illustrated in the diagrams above and below.



In the current research, IWYP scientists are selecting high biomass and high photosynthetic lines and then finding the genetic markers that are associated with these traits. IWYP researchers are also finding genes that increase photosynthesis and biomass, and showing that these create higher biomass lines in the field. These complementary approaches are powerful and vindicate the science targets on which IWYP is based. The expected discoveries for the coming years are displayed on the timelines in the figure below.



STRATEGIC GOALS FOR THE NEXT 5 YEARS

To ensure the flow and release of new high yield germplasm, the top strategic goals of IWYP for the next 5 years are to:

- Bring in more science, funded or collectively through joint Calls or by national aligned Calls or though integrating existing single projects to ensure success by more targeted "shots-on-goal" and to build out / balance the IWYP Science Portfolio
- Maintain active Program management of the Portfolio to Coordinate the Science Program for research synergy and operational efficiency. It will continue to integrate current research projects and identify opportunities to generate additional added value
- Continue to develop the IWYP Hub and ensure capacity for future needs. This includes pushing the first project discoveries through validation, combination and prebreeding, and optimizing the processes at the IWYP Hub for prebreeding for precision, efficiency and speed
- Explore the potential to establish a Virtual Hub for pushing discoveries faster into winter wheat through a separate public-private partnership
- Deliver the first higher yielding germplasm developed with IWYP tools and traits
- Bring in new public and private Partners, and additional cash and in kind resources, including different types of partners to support specific facets of the IWYP Science Program, especially the more downstream development stages
- Ensure that the research projects and the IWYP Hub have a strong component for training the next generation of wheat scientists and capacity building
- Remain focused, avoid scope creep and deliver the yield potential element of the wider Wheat Initiative Strategic Research Agenda

The basis of the IWYP strategy is to:

- Seek breakthroughs and not incremental improvements
- Exploit the best relevant science base worldwide
- Coordinate and integrate the science teams
- Integrate the research discoveries and generate added value
- Incorporate the research discoveries in elite germplasm and evaluate
- Transfer the improved germplasm to leading breeding programs around the world, both public and private
- Maximize worldwide impact by making results and germplasm open for adoption in different geographies without restriction

Measuring Success

IWYP will measure its overall success in many ways, although this is a difficult task given the complexity of research, development, breeding and trialing processes. However, certain benchmarks will be used to measure the impact of IWYP research outputs and improved germplasm over time. First, we will assess the magnitude of relative improvements during the research phases. Next, we will measure the progress of yield improvements relative to current levels via internal and international trials. As breeders and other researchers will continue to make gains in yield, we will also assess our cumulative gains in yield performance levels against the best commercially planted varieties over time. Another good measure will be to assess the level of uptake of IWYP germplasm into breeding programs worldwide. Baseline metrics and progress to date are under development.

RESOURCES – NEEDS, SOURCES, TIMING

Financials

The IWYP financial plan is built upon investments from the many IWYP Partners, each of which funds or underwrites specific components of the total IWYP operational and research activities. Government agency partners that support scientific discoveries (currently in the UK, USA, Australia, Canada, France, India, and Mexico) are responsible for the activities where investments are usually research project based and made in multi-year assignments (grant awards). USAID, BBSRC and SFSA currently invest in the development pipeline downstream of discovery (IWYP Hub) through a commission to CIMMYT in Mexico, while private sector wheat breeding companies provide the resources for their own private sector pipelines necessary for commercialization of new varieties, including product development (breeding), marketing and sales. The

final steps of product development and deployment of new varieties in developing countries come from sustained investments by the national programs or small local seed companies of the countries involved.

Through its partners, IWYP has an overall goal to invest US$100 million over the next 5-10 years to realize its aims. To date, over US$45 million has been committed to delivering the strategy. It is notable that due to the desire for IWYP outputs to be widely available and not constrained by intellectual property, the private sector does not receive or contribute cash to the research projects but does provide in-kind support to individual projects of interest. New investments into the discovery science enter IWYP together with the selected scientific projects ensuring that no additional costs are incurred. However, for IWYP to achieve its overall goals and objectives and deliver the discoveries in the form of higher yielding wheat varieties, more resources are needed. In particular, additional sustained funding is critical in the areas of operation and research coordination, and especially to support the essential IWYP Hub technical development platform which is intended to continue its development activities and generate added value for years after the research projects are completed.

If the research is not coordinated, integrated, developed through prebreeding and delivered to breeding programs by IWYP Management and the IWYP Hub, we risk losing the opportunities to practically apply and capitalize on the step-change research discoveries that are beginning to be delivered by the researchers. The pipeline costs for the IWYP Hub at CIMMYT are covered for 2017 (currently ca. US$1 million per year) but additional investments are needed for 2018 onwards, as are investments to cover the relatively small and cost effective management overheads. This will likely require more partners to be brought into IWYP as well as new different types of partners that prefer to fund downstream and delivery aspects rather than discovery research. Therefore, the IWYP Executive Board and Management will continue to seek new partners and funds to enable the strategy to be fulfilled. This is essential for wheat yields in farmers' fields to be boosted substantially to contribute in global food and nutritional security in the future.

ANNEX

IWYP Employs a Strategy to "Approach the Issues Differently"

- ◊ *A research program that seeks step-changes, takes risk and is metrically driven to coordinate, plan, integrate results and maintain focus*
- ◊ *A commitment to collaboration and the overarching objectives and goals*
- ◊ *A structure that enables flexibility and responsiveness*
- ◊ *Coordination, transparency and inclusiveness facilitated by independent management to ensure success, both technically and operationally*
- ◊ *A focus on delivery with a strong sense of urgency*
- ◊ *A commitment to the competitive funding processes*
- ◊ *Synergistic approaches to avoid duplication of activity and competition*
- ◊ *Open communication of results and exchange of germplasm, data and materials as necessary to achieve the overall research and delivery objectives*
- ◊ *Coordination and integration of the overall program to generate added value*
- ◊ *A central downstream development platform to deliver discoveries in elite germplasm and push them toward deployment*
- ◊ *Strong linkage with the private sector in all aspects*
- ◊ *A focus on increasing yield to facilitate uptake of other beneficial traits for nutrition, sustainable production, stress tolerances, etc.*
- ◊ *Building of an international community / wheat yield research network to link and capitalize on relevant research funded outside of IWYP*

IWYP CURRENT RESEARCH PROJECTS

Science areas of the IWYP funded projects

- Finding and employing traits and genes to increase photosynthesis
- Discovering genes to boost spike development
- Reducing respiration and thereby enhancing photosynthetic efficiency
- Optimizing canopy architecture to increase carbon capture and conserve nitrogen
- Using selected genes from other species to increase biomass and yield
- Optimizing phenology leading to increased harvest index
- Deploying genome editing technologies to create novel variation that leads to significant increases in the genetic yield potential of wheat
- Enhancing photosynthesis to impact the deposition of carbon compounds during plant development.
- Developing methods of measuring yields and other important phenotypic traits in field plots using new technologies
- Developing practical systems for facile implementation of hybrid wheat breeding programs leading to commercial production of hybrids.
- Validating, characterizing and deploying QTL for grain yield components including grain weight / grain size, spike architecture, sink dynamics, floret number and fertility, phenologies, sucrose transport, carbon assimilation, carbohydrate mobilization and partitioning, spike photosynthesis, and enhanced carbon capture (large USDA NIFA CAP project)

Science areas of current IWYP "Aligned Projects"

- Defining the underlying genetic regulatory factors for increased photosynthetic efficiency and their functions, then developing markers to facilitate breeding with best alleles
- Selecting traits for increased biomass and increased canopy photosynthesis from diverse populations
- Selecting traits that increase harvest index and developing efficient selection approaches to identify them
- Employing upright canopy architecture to enhance radiation use efficiency
- Exploring the yield potential of novel spike architecture
- Increasing yield through regulation of plant growth mechanisms