Durable Rust Resistance in Wheat

Project Summary

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Charitable Purpose

To systematically reduce the world's vulnerability to rust diseases of wheat through an international collaboration of unprecedented scale and scope.

Project Description

The ability of the world's farmers to meet current and future demand for wheat is gravely threatened by the highly virulent stem rust population emerging from East Africa. This project will aggressively mitigate that threat through coordinated activities that will a) replace susceptible varieties in the short and medium term with seed of durably resistant varieties, created by accelerated multilateral plant breeding, and delivered through optimized developing country seed sectors; and b) harness recent advances in genomics to end the wheat-rust "arms race" by introducing non-host resistance (immunity) into wheat. This project will induce an irreversible quantum leap in international collaboration in wheat research, thereby enhancing the globe's capacity to address the pressing issue of increasing annual wheat production by 50% (ca. 300 million tons) by 2020.

Introduction

Virulent on most of the world's deployed wheat varieties, a new race of wheat stem rust, designated as Ug99, threatens global food security. At the request of Dr. N.E. Borlaug, in March of last year Cornell University assembled world experts in Cd. Obregon, Mexico, to consider the feasibility of rendering wheat a non-host to stem rust by exploiting recent advances in functional and comparative genomics. The immunity of rice to rust drives this notion. Participants endorsed engagement in the long-term research goal of ending the wheat-rust arms race through engineered non-host resistance (NHR). Participants also recognized the potential and essential need for immediate impact through expanded investments in the scale and coordination of the applied, conventional breeding and seed sector efforts promoted by the Global Rust Initiative (GRI) established by CIMMYT, ICARDA, FAO, USDA-ARS and Cornell University as an outcome of the May 2005 assessment[1] (see Recommendation #10) of race Ug99 in Kenya and Ethiopia and the potential for impact in neighboring regions and beyond.

The Bill and Melinda Gates Foundation encouraged Cornell to translate these conclusions into a comprehensive proposal seeking solutions to the threat of Ug99 through research investments in both conventional breeding and non-host resistance. A subsequent iterative process involving the Foundation, Cornell, and numerous national and international institutions in both the developed and developing world resolved a set of revised Project Objectives with primary emphasis on expanding the scope, scale, and coordination of the activities that would result in the world's farmers sowing wheat varieties with durable resistances to stem and other rusts.

Cornell and its partners present here a set of Activities within seven science Objectives that, if implemented, will strengthen and expand current capacities to create developing country-targeted conventional wheat varieties with rust resistance bred to be durable over space and time. One Project Objective addresses NHR.

A significant outcome of this process was recognition that the world's inability to conduct a coordinated defense against Ug99 reflects a strategic shortfall in planning, investments and policies in both national and international spheres. Accordingly, this proposal contains an Objective for advocating and coordinating global awareness and cooperation with the aim of expanding engagement and investments by multiple stakeholders in an effective, coordinated response to stem rust of wheat. The Project aims to facilitate the transition of the Global Rust Initiative into the Borlaug Global Rust Initiative and enable that body to serve as an overarching umbrella through which rational, integrated, and appropriately funded global rust research is achieved.

The Project described here has a three-year timeframe and includes a two-year Planning Objective designed to facilitate development of a much more inclusive proposal for submission to the Foundation in 2009. The Activities in the Planning and Advocacy Objectives, running parallel to significant investments ramping up international breeding efforts (and initial engagement in NHR), will enable development of a Phase II Project with strengthened impact

[1] Sounding the Alarm on Global Stem Rust, 2005. CIMMYT, ICARDA, KARI, EARO, and Cornell University.

pathways (e.g., accelerated seed replacement systems for resource poor farmers), coordination, and NARS participation. The Planning and Advocacy Activities will also facilitate identification of the best science and engage the best scientists in the Project. They will also help leverage more investments by Donors and NARS through pro-active educational outreach and provision of a Web-accessible knowledge base both "making the case" and cataloging needs and opportunities. Combined, the outputs of the Planning and Advocacy Objectives will enhance focus and impact on resource poor farmers.

Background and Rationale

Stem Rust: Historical Perspective

Stem rust is the most feared disease of wheat. Stem rust spores arriving as late as one month before harvest can turn a previously healthy crop into a tangled mass of stems, which produces little to no grain. Moderately infected fields can produce as many as 10^{11} spores/hectare, many of which are picked up by wind currents. The result is that astronomical numbers of rust spores can be moved hundreds or thousands of kilometers to infest other regions. In the 1953 pandemic in North America, rust spores produced in fields in Kansas were deposited across 100,000 km^2 of wheat 1,000 km north in North Dakota and Minnesota at a rate of over eight million spores per hectare. The result was loss of 40% of North America's spring wheat crop. Although individual fields can be annihilated, on a regional basis, average yield losses under epidemic conditions are commonly 10%, enough to have disastrous humanitarian effects on wheat producing countries in the developing world, as well as substantial secondary impacts on the entire global economy. Pandemics have been noted throughout history, with significant events occurring in South Asia, China, Central Asia, East and Central Europe, North America and elsewhere in the past 130 years. The last major continental pandemic was that described above in North America. The episode triggered international collaboration that helped lay the groundwork for the Green Revolution wheats. Although stem rust epidemics have occurred since 1955, they were relatively localized (e.g. 1973 and 1974 in Australia and the SE United States, respectively; and 1992 in Ethiopia). This 40-year period where stem rust was largely quiescent is a result of genetic resistance.

Genetic resistance to stem rust has been a priority objective of wheat breeders for over 100 years. The period between 1900 and 1955 saw the discovery and deployment of various major resistance genes, which are sufficiently potent that they can preclude stem rust spore production even if a plant possesses only that single gene. Their hallmark phenotype is the hypersensitive response. These genes are "race specific" and function only if the infecting population of stem rust is a race that lacks "virulence" to that specific wheat resistance gene. They are also known as "seedling resistance genes" because their presence and identity is determined by seedling assays (note that this type of gene also imparts resistance to adult plants where resistance is needed to prevent yield loss).

From 1955 onward, most of the world's wheats, including the Green Revolution varieties, were protected by both seedling resistance genes and a second class of resistance genes that only function in the adult stage. These genes are referred to as adult plant resistance (APR) genes.

APR is generally considered to be race non-specific and dependent on several genes, each with minor, additive effects.

Before 1955, stem rust resistance was not effective over time (i.e., durable) because the pathogen was able to spawn virulent races rapidly, which “defeated” the race-specific genes upon which resistance was based. Wheat production was in a continual boom-bust cycle where a variety seemingly unaffected by stem rust in one year was annihilated the next. This boom-bust phenomenon as it relates to wheat stem rust is not a product of modern plant breeding—experts believe that some Biblical references to plagues refer to stem rust. The past 60 years have witnessed expanded wheat production and productivity yet stem rust has not been a significant problem.

In that same period, wheat improvement specialists continued to improve wheat for many other characteristics and together with improved agronomic practices, wheat scientists and farmers have kept wheat supply moving in step with increasing demand the past four decades. Partly because of these successes, two critical features of a resilient wheat improvement system were allowed to decay:

1. the capacity (human and infrastructure) to work with stem rust; and
2. the release frequency of varieties with durable, race non-specific stem rust resistance.

A third factor—a robust collaborative international network of wheat improvement institutions and scientists—has also atrophied.

Ug99

In 1998 a Ugandan crop scientist collected samples of a stem rust variant that appeared to be virulent on the previously undefeated and widely used major gene *Sr31*. The sample was multiplied on universal susceptible wheat and then used to challenge a series of wheat stem rust genes in a process called pathotyping. This bioassay demonstrated that the Uganda isolate represented a unique pathotype (or race), which had a unique and potentially dangerous virulence pattern. In formal terms, this race is designated TTKS, but it is widely known by the name given the isolate: Ug99 (“Ug” for Uganda; “99” for the year its discovery was published). By 2004 Ug99 had colonized wheat fields of both Kenya and Ethiopia. An expert panel report, “*Sounding the Alarm on Global Stem Rust*,” issued May 29, 2005, unequivocally declared Ug99 to be a threat to world wheat production (see www.globalrust.org). The report predicted that Ug99 would migrate across the Red Sea to Yemen, then to the Middle East, and subsequently to Central and South Asia. The predicted immediate path of Ug99 to South Asia covers a region that produces 19 percent of the world’s wheat (ca. 117 million tons) with a population of one billion people. It is likely that either wind currents or inadvertent transport will eventually carry Ug99 to North Africa, Europe, West Asia, China, Australia, and the Americas.

Collaborative research since early 2005—under the umbrella of the CIMMYT (International Maize and Wheat Improvement Center) and ICARDA (International Center for Agricultural Research in Dry Areas)-led Global Rust Initiative (GRI), initiated by Dr. Norman E. Borlaug—has established that Ug99 defeats virtually every race-specific resistance gene used in commercial varieties grown throughout the world. Ug99 defeats more of the 50+ known major resistance genes than any previously known stem rust lineage. In 2006, researchers discovered in

Kenya a variant of Ug99 that defeats the widely used stem rust gene *Sr24*. This even more dangerous race will follow the same path that Ug99 is on. Over 90 percent of the world's commercial wheat varieties are susceptible to the new variant, including almost all the wheat on the predicted path between East Africa and South Asia. Without swift intervention, stem rust will re-establish itself as a chronic cause of lost production in vast tracts of wheat in the developing world.

In January 2007, it was confirmed that Ug99 had migrated from eastern Africa and was infecting wheat in Yemen in the Arabian Peninsula. Scientists are convinced that the Ug99 lineage will reach the Middle East in the immediate future.

Potential Impact of Ug99 on the World's Poor

Wheat represents approximately 30% of the world's production of grain crops. The FAO predicts that 598 million tons of wheat will be harvested this year on 220 million hectares of land. Nearly half of that production will be harvested in developing countries. On average, each person in the world consumes 68.2 kilograms of wheat each year. That equates to about 630 calories per day per person, or 1/2 to 1/3 of the minimal energy requirements of most adults. In West Asia, North Africa, and Central Asia, wheat provides more calories than all other grains combined. The Middle East and North African countries consume over 150% of their own wheat production and are thus heavily dependent on imports.

Once Ug99 and its derivatives have established themselves in North Africa, the Middle East, and South Asia, annual losses could reach US$ 3 billion in any given year. The effects on rural livelihoods and geopolitical stability would be incalculable. Large populations of poor wheat-growing farming families would be seriously affected and few would have alternative livelihoods. The impact on landless laborers dependent on agricultural jobs would also be severe, and one could anticipate an increase in the rural-urban migration of landless laborers and small farmers. Moreover, such large production losses would have significant implications for rural and national economic growth rates in seriously affected countries and could even affect global wheat markets.

The Green Revolution introduced semi-dwarf wheat varieties developed in Mexico by Nobel Laureate Dr. N.E. Borlaug to various developing countries during the 1960s and 1970s. It not only helped feed the world at a time of impending famine but also triggered an industrial revolution in subsequent years. Increased crop production did not come just from the semi-dwarfs' high yielding ability and higher input efficiency but also from their genetic resistance to the rust diseases. This resistance has saved billions of dollars annually by avoiding devastating epidemics that would have had major effects on global food supply and prices.

Were it not for rust resistant wheat varieties, resource-poor farmers who cannot afford pesticides would still be at the mercy of such epidemics. The best control strategy for poor farmers in the developing world—and the most environmentally friendly and profitable strategy for commercial farmers everywhere—is to grow genetically resistant crop varieties. To give an example, protecting one hectare of wheat from stem rust disease in the highly productive Nile Valley of Egypt would require two applications of fungicides, at a cost of US$ 80. This lost income is equivalent to 8-10% of wheat productivity in the area, which stands at about 6 tons per hectare. Fortunately, cultivation of resistant wheat cultivars has avoided the excessive use of chemicals in about two-thirds of the 220 million hectares sown to wheat worldwide. Use of resistant varieties thus increases profit margins, helps keep the prices of staple crops at affordable levels, and has a beneficial effect on human health because fewer agrochemicals are applied.

The Solutions

Fortunately, Ug99 does not defeat all known major genes, and recent research in East Africa shows that minor-gene-based adult plant resistances are also effective. These resistances can and must be bred into varieties that exhibit performance and quality characteristics that will enable their acceptability to farmers. Phenotyping breeding progeny for response to the Ug99 lineage must be done in East Africa today for bio-security reasons (the migration is as of yet limited); and in future because East Africa is likely to be a breeding ground of new stem rust variants for the foreseeable future. Intensifying the International Centers' wheat improvement programs to enable maintenance of yield gains while including stem rust resistance in the profile of previously required characteristics (including resistances to leaf and yellow rusts) will generate Ug99 resistant varieties for much of the immediate threat area. Aggressive variety testing and multiplication tactics must be pro-actively encouraged to ensure availability of seed. An under-utilized developing country wheat research network must become reacquainted with a dangerous foe that many have not ever seen. The migration and evolution of Ug99 and its inevitable derivatives must be monitored to provide scientists information on which genes or gene combinations remain effective and to inform policy makers about choices in research investments, plant protection, etc. Prudence dictates we engage in targeted searches for additional resistance genes while simultaneously employing cytogenetic and molecular marker technologies to improve the utility of effective genes, and to develop tools that will speed their deployment in farmer's fields.

In a longer term approach, we propose to exploit the rapidly expanding body of knowledge of plant host-pathogen interactions, coupled with the availability of specialized genetic resources in rice, to search out paths to unraveling the mystery of why wheat succumbs to rusts and rice and some other species do not.

Project Objectives

It is important to pursue short-term goals that will achieve the rapid replacement of Ug99 susceptible wheat with resistant wheat. This means accelerated deployment of the small number of varieties already identified as possessing putative durable resistance (two or more major genes or minor-gene-based APR). For the medium term, the genetic diversity of effective durable resistances needs to be broadened to ensure avoidance of the boom-and-bust cycle inherent in reliance on only a few sources of resistance. Rice is the only cultivated cereal that is immune to the entire taxon of rust fungi. With advances in the area of genomics and molecular biology, technology now exists that allows for the identification of the genetic components responsible for the resistance. Gene transfer technology in both wheat and rice has advanced to the point where transferring this resistance trait from rice to wheat is feasible. Thus, the long-term research goal of this project is to identify and transfer non-host resistance genes from rice to wheat to achieve immunity to rusts in wheat.

Objective 1. Planning for the Threat of Emerging Wheat Rust Variants

This Objective will have a two-year budget. The Project Coordinator will lead this Objective. The primary output will be an inclusive, high science, high impact Phase II proposal ready by June 2009. Spillovers into the Advocacy arena (Objective 2) are likely in cases where high impact science concepts are identified that either fall outside the scope of the Foundation's interests; or are funded via alternative sources through the Advocacy efforts. Phase II must have a significant number of NARS partners to be successful. Full consultation with any potential partner will be facilitated by the Project Coordinator.

Six meetings will be funded, facilitated, and attended by members (one or more) of the Cornell management team. Non-project scientists from at-risk NARS will also be invited and funded as participants. The number of non-project NARS scientists will range from 2 to 15. External Project Advisory Committee (see Objective 10) members will be invited and outside experts will be included as consultant observer/participants. Where possible and appropriate, Team Leaders of complementary Objectives will be included in Objective-level workshops.
Two topic-specific convenings will be held. These will be "big-tent" free-thinking gatherings of the world's best minds with the aim of stimulating early conceptualization of ideal combinations of science, people, and resources to address Activity 1.2, molecular marker technologies in wheat (particularly SNPs) and Activity 1.1, the role of recent advances in pathogen genomics and molecular biology in the defense of the world's wheat crop. Each convening will be orchestrated with the aid of an expert in the field employed as a consultant. Both of these convenings will be held in conjunction with pre-planned symposiums, or similar gatherings. Two to four of the ten non-project participants will be from at-risk NARS.

Two workshops will be held for geographically and institutionally dispersed Project scientists working on a common Objective. These workshops are considered part of Activity 1.3. As with all meetings, these will include experts from outside the Project but are aimed at facilitating intra-project communication and resolution of best practices that can be implemented during Phase I, and/or planned for Phase II. The two Phase I Objectives that will hold workshops are Objective 5, Breeding (in conjunction with the ICARDA-CIMMYT Wheat Improvement Program meeting) and Objective 9, Exploring Rice Immunity to Rust. Both of these workshops will be orchestrated with the aid of an expert in the field employed as a consultant. Fifteen non-project NARS participants would be supported for the Breeding workshop (location somewhere in CWANA). The Exploring Rice Immunity to Rust Workshop would be held in China and two to five NARS non-project participants would be supported.

The first Annual Workshop of the Durable Rust Resistance in Wheat Project will be held in Cd. Obregon, Mexico in March 2009. Obregon is where CIMMYT's Global Wheat Program conducts its winter breeding cycle. This workshop is considered part of Activity 1.4, and is planned to be combined with a full meeting of the Borlaug Global Rust Initiative. This Objective would facilitate the BGRI meeting including venue fees; Objective 2 would advocate for sponsorship, and support 25 non-project NARS participants. The Project Workshop would seek to facilitate information exchange, updates on progress, and an update on the status of the Phase II planning. The External Project Advisory Committee and outside expert consultants would participate.

The Phase II planning process would be fully activated by January 2009 (Activity 1.4). The Cornell Management team, in consultation with the External Project Advisory Committee and Project Team Leaders, will engage in a process of identifying the outline of the Phase II proposal. This would be informed by the workshops and convenings held earlier. Before the Cd. Obregon Project Workshop, Phase II team leaders would be identified and draft logframes and milestones circulated. Broad outlines of the developing Phase II would be shared at the general Cd Obregon meeting. Immediately following the combined Project Workshop/BGRI meeting, a Phase II Planning Workshop (part of Activity 1.4) would be held with identified Team Leaders, BMGF personnel, outside consultants, and the External Project Advisory Committee. The outcome of this workshop will be an agreed process, schedule, and associated responsibilities that ensure a first-class Phase II proposal is ready in June 2009.

Funding will be provided for the two scientists working in Objective 7 (reducing linkage drag) to travel to the International Wheat Genetics Symposium as part of Activity 1.4. Funds to facilitate visits by these scientists to cytogenetics labs in Australia after the meeting are budgeted. The aim is for Objective 7 to build partnerships and leverage access to genetic resources and knowledge.

This Objective will also orchestrate a process that resolves country specific plans to optimize the seed sectors (Activity 1.3). Seed is the most efficient mechanism for delivering rust resistant wheat varieties to farmers. Inadequate or late availability and access to quality seed is expected to be a limiting bottleneck to rapid adoption and dissemination of new durable rust resistant varieties and associated production technologies. Weaknesses in national seed systems will be very situation dependent. The main vehicle of planning for this objective will therefore be consultant-assisted consultative planning sessions in which country specific interventions are identified to ensure that seed of improved, durable rust resistant varieties becomes available to at-risk farmers as rapidly as possible. Tightly specified, concise analyses of a country's wheat seed sector (generated by a consultant) will be developed in consultation with target country's NARs leadership. Meetings with agendas drawn up in consultation with the NARs leadership, and informed by the wheat seed sector analysis, will be conducted with the aim of identifying policy, logistical, or other barriers to minimizing the time from identification of new varieties to the time of their impact in farm fields. Targeted countries in this phase are Kenya, Ethiopia, Egypt, Turkey, Iran, Pakistan, and India.

This Objective will also facilitate planning for Socioeconomic Monitoring and Assessment as part of Activity 1.4. Generating appropriate information and creating awareness among policy makers and other decision makers about the threat of stem rust are essential in establishing the right impact pathways for resistant wheat varieties and other technologies to mitigate the negative impacts. Socioeconomic monitoring, impact and vulnerability predictions are needed to provide inputs into decision support systems to inform interventions that mitigate production losses, and facilitate and expedite preemptive actions at local, national and sub-regional levels. The objective in planning for the socio-economic monitoring and assessment activity will be to determine the appropriate means of assisting wheat farmers and agricultural policy and decision makers to reduce vulnerability to stem rust race Ug99 and other virulent races of rust. We will actively encourage a dialogue and identify promising leaders in the area of developing socio-economic decision-support tools and policy options that can mitigate the effects of production losses on local, national, and global wheat economies and at-risk farmers and poor consumers.

The data generated by the project partners will be diverse and will include information from breeding programs, rust screening, international nurseries, genetic mapping, marker development and haplotyping. However, not all of these data types need to be integrated into a single database scheme as once envisioned. The most suitable database system available will be identified for each, and where possible, integrated into the Project Website developed in Objective 2. Resolution of the solution to information management will be orchestrated by the Project Coordinator as part of Activity 1.4.

Objective 2. Advocating and Coordinating Global Awareness and Cooperation.

The world's inability to conduct a coordinated defense against Ug99 reflects a strategic shortfall in planning, investments, and policies in both national and international spheres. Correction of this shortfall requires a framework for coordinated action as well as informed advocacy for appropriate activities and commensurate investments by an array of agencies.

Activities of this Objective will address the needs in coordination and advocacy through establishment of an Advocacy and Coordination Office that will coordinate the Durable Rust Resistant Wheat Project, promote linkages with other partners, act as the Secretariat for the Borlaug Global Rust Initiative (BGRI), and promote/facilitate informed advocacy. The Advocacy and Coordination office will be managed by the Project Coordinator, who will also act as Facilitator for the BGRI.

The BGRI, formed by the UN-FAO, CIMMYT, ICARDA, and Cornell University, represents formalization of the Global Rust Initiative (www.globalrust.org). Chaired by Dr. N.E. Borlaug, the BGRI represents a framework for coordinated global action in the battle against wheat rusts. This linkage yields substantial leveraging of the Foundation's investments, and amplifies the Project's capacity to enlist additional players through advocacy.

For maximum effect, advocacy must be informed by real-time knowledge in three areas:

1. The gap between what <u>is</u> being done in terms of research and development, as compared to what can and <u>should</u> be done;
2. The identity, interests, and capacities of current and potential investors; and
3. The identity, interests, and capacities of current and potential actors in the realm of research and development.

Accurate knowledge in these three areas depends on up-to-date awareness of advances in science and technology related to the wheat rust problem.

Today, there is no compilation of investors or research/development agencies and no single source of information on the states of relevant sciences and technologies related to the wheat rust problem. In turn, these deficiencies render nearly impossible the task of describing the status quo, or the best case scenario as regards activities and investments. Taken together, these deficiencies preclude both informed advocacy, and coordinated global action.

Accordingly, the Advocacy and Coordination Office will create a Web-accessible wheat rust knowledgebase/portal. The knowledgebase will provide Project personnel, laymen, scientists, and donors/investors with:

- Global inventories of research institutions working on wheat rust including ARIs, IARCs, and NARS with information on:
    - research personnel,
    - capacities, and
    - projects;
- Global inventories of donors, traditional and non-traditional, international, regional, and country-specific, including contact information and priorities;
- Global inventories of professional societies and other international advocacy groups; and
- Tools for facilitating communication leading to partnerships and coordinated action.

The wheat rust knowledgebase will be accessible through the Project Website, which will be funded and maintained under this Objective and Objective 10. The Advocacy and Coordination Office staff will keep current the information in the wheat rust knowledgebase, and also employ it as a general tool in Advocacy and Coordination. The staff will also generate an annual "gap analysis" showing the shortfall between actual funding and research, and what is needed.

The Advocacy and Coordination Office will employ the Project Website to facilitate communication and coordination among and within the Project's science Objectives, as well as provide for communication and coordination between the world at large and the Durable Rust Resistant Wheat Project.

The Advocacy and Coordination Office and wheat rust knowledgebase/portal are outputs of Activity 2.1. Project Coordination and promotion of linkages with other partners are outputs of Activity 2.2, while Advocacy and support of the Borlaug Global Rust Initiative are outputs of Activity 2.3.

The Advocacy and Coordination Office will also promote awareness of the importance of robust policies and strategies for optimized gene deployment (Activity 2.4), and conduct special initiatives as need/opportunities arise (Activity 2.5). The staff of the Advocacy and Coordination Office is funded for substantial travel to facilitate Project coordination (programmatic) both internally and with other actors. Travel funds will also facilitate direct advocacy by Cornell Project staff and by significant personages such as Dr. Borlaug.

Objective 3. Tracking Wheat Rust Pathogens

Directed, optimized mitigation of the threat of stem rust to resource poor farmers cannot be achieved without vigilant monitoring of the incidence and nature of stem rust in countries thought to be Ug99-free today, and in those where Ug99 is already established. The stark fact is that today, we do not know how far Ug99 or its derivates have migrated. Lack of this knowledge impedes resolution and adoption of appropriate national and international policies, investments, and strategies in plant protection, plant breeding, seed systems, and research on the stem rust pathogen. It is insufficient to predict the pathways by which the Ug99 lineage will migrate, since mutation and sexual recombination (especially in East Africa and Central Asia where the alternate host is endemic) will spawn new variants; variants whose characteristics may dictate changes in gene deployment strategies in both the choice of gene combinations used by breeders, and in the distribution and retirement of varieties by national seed sectors. Such variants can arise anywhere, not just East Africa.

Currently, however, no framework exists for acquiring and sharing data on incidence, severity, and genetic composition of stem rust infections in the developing world. Likewise, there is no singular source of information on the spatial and temporal distribution of wheat (or wheat varieties) in these regions through the course of a year. Combined, these deficiencies preclude directed, efficient action by scientists and policy makers tasked with mitigating the threat to cereal production posed by wheat stem rust.

We propose to correct these deficiencies by establishment of a Global Cereal Rust Monitoring System (GCRMS), which will network capabilities and operations in the Middle East, North Africa, Asia, and Africa. The GCRMS will enable dissemination products in a spatial framework with information concerning the distribution and nature of both stem rust populations, and the wheat rust resistance genes of popular varieties. This requires geo-referenced data on the circumstances of stem rust infections, capture of samples of the rust (and in some cases the host plants), subsequent analysis of the samples; and compilation of the combined data in a GIS information storage and analysis platform.

Following the organizational model and data flows of the UN-FAO Desert Locust Monitoring system, the GCRMS will be composed of a UN-FAO based International Focal Point (IFP), NARS supported National Surveillance Teams (drawn from both Plant Protection and Research Institutions), a Coordinating Pathologist based at the U. of Sydney, and various international partners including ICARDA, CIMMYT, USDA-ARS, U. of Free State (South Africa) and Agriculture Agri-Foods Canada. At the international level, data management and dissemination products will be coordinated by the IFP (Activity 3.3). National operations, data management/analysis, and integration with the GCRMS will be the responsibility of National Focal Point (NFP) persons within each of the National Surveillance Teams that conduct surveys (Activity 3.3). Transfer of biological samples to Advanced Research Institutes for follow-on characterization of stem rust and host plant samples will be moderated by the Coordinating Pathologist. The Coordinating Pathologist will also provide quality assurance for data generated from analysis of stem rust and host plant samples and subsequently passed to the IFP (Activity 3.4).

The information platform and associated baseline datasets (e.g., spatial and temporal aspects of wheat production) will be generated by ICARDA, CIMMYT, and the FAO IFP in partnership with the NARS (Activity 3.1). National Surveillance Teams will be provided training on standardized protocols for collection of geo-referenced survey data and samples (Activities 3.1 and 3.2). NFPs will coordinate in-country sample preservation; where possible, in-country analysis of data; and transfer of data to the International Focal Point based at the FAO. NFPs will also facilitate where possible in-country virulence detection, race analysis, and DNA fingerprinting of stem rust samples; and host resistance gene detection with host plant samples. Host resistance gene detection (by DNA markers) is an indirect means of postulating the virulence(s) carried by stem rust at a given survey point. Initially, it is expected that much of the stem rust and host plant sample analyses will be conducted at one of three Advanced Research Institutes in Australia and North America. The Coordinating Pathologist (based at the U. of Sydney) will coordinate movement of samples to the Australian and North American laboratories, and provide data quality control for pathogen/host data sent to the central data platform of the GCRMS.

The GCRMS and associated training, field work, and sample analyses described here all focus on stem rust. The system will, however, be designed to accommodate eventual inclusion of similar activities with yellow and leaf rusts of wheat. This approach enhances the likelihood of success and ensures focus on the new threat posed by stem rust Ug99. During Phase I of the project, primary emphasis will be placed on creating a system that can report the distribution and nature of stem rust. The nature of the proposed system renders it amenable to integration with meteorological and other geo-referenced data, including socio-economic and agro-ecological attributes of resource poor farmers threatened by stem rust. In turn, that will provide the basis for prediction of stem rust migration and impact on resource poor farmers and the global economic system.

Some countries already conduct surveys (India, Iran, Turkey, Ethiopia, Kenya), but many do not. None are networked into multi-national reporting systems. The Advocacy activities in Objective 2 of this Project will target NARS conceptual buy-in, rely on existing personnel, and seek to mobilize combinations of National funds and bi-lateral donor support for operations of National Surveillance Teams. Objective 4, Critical Facilities, by addressing the training and funding for surveillance and in-country race analysis (pre-requisites to optimized phenotyping shuttle sites), will enable Ethiopia and Kenya to participate in the GCRMS and eventually become centers of excellence that can play enhanced roles in Phase II of the Project.

Locating the IFP as a UN-FAO employee within the Desert Locust Forecasting project leverages enormous expertise and information access that this highly experienced group possesses. Further leveraging derives from the in-country support of the National Surveillance Teams, and engagement of the stem rust labs of the three industrialized countries that have extensive experience in stem rust surveillance (Australia, USA, and Canada). This Objective represents a tremendous opportunity to solve a major problem (lack of on the ground information), while simultaneously engaging every single at-risk country in a unified, networked system that by its very nature will generate a cadre of stakeholders with hands-on experience with stem rust. This is the only Objective that provides a framework for generating the virtual community targeted in the advocacy aspects of Objective 2.

Objective 4. Supporting Critical Rust Screening Facilities in East Africa

Protection of world wheat through development of varieties with durable resistance to Ug99 requires expansion of recently initiated collaborative research in East Africa. All activities that require accurate phenotyping of adult plants require these critical facilities in the center of origin of new and dangerous forms of stem and yellow rust. Significant investments were made in Kenya to monitor the occurrence of cereal rust variants both by Canada (until the 1970s) and

CIMMYT (until the 1990s). The occurrence of Ug99 and its virulence on most currently cultivated varieties world wide has brought this region back into focus as a critical component of the world's wheat research system. In collaboration with CIMMYT and ICARDA scientists, research conducted since 2005 at the Kenyan Agriculture Institute's (KARI) Njoro Research Center and several facilities of the Ethiopian Institute of Agriculture Research (EIAR) was instrumental in establishing the true scope of the threat posed by Ug99. Wheat producing nations throughout the world participated in testing the reaction of wheat (over 20,000 research plots) in both the main and off seasons in Kenya and Ethiopia since 2005. This effort documented global wheat vulnerability to the Ug99 lineage, determined which of the named stem rust genes are effective against Ug99, and revealed the existence of minor gene adult plant resistance. This groundwork has also established once again the value and practicality of operations in East Africa.

This Objective is designed to expand the capacity of KARI and EIAR to phenotype wheat genetic resources in support of the overarching objective of development and adoption of wheat with durable rust resistance. Fully operational critical facilities in East Africa require investments in field, greenhouse, and laboratory facilities and equipment, as well as operational support for mission-dedicated teams of national and international scientists. These critical facilities will enable management and manipulation of large numbers of genetic stocks (or isolates) of both host and pathogen. Twelve hectares of irrigated land will be dedicated to this work (4 hectares available per season to accommodate a 3-year rotation) at Njoro, Kenya, and 3 hectares per season will be used at Debre Zeit in Ethiopia. Pathogen management (inoculum production, etc.) will be done at Njoro for the Kenya operation, while that work will be done at a central rust laboratory at Ambo in Ethiopia. Ambo also will be provided resources to enable race typing. Njoro will be the primary bread-wheat phenotyping site and Debra Zeit will be the primary durum-wheat phenotyping site. The project will support critical facility teams composed of KARI (Kenya) and EIAR scientists. A CIMMYT scientist posted to Kenya will have overall responsibility for operations in both countries.

In-service learning opportunities will be provided by 1) one- to three-week collaborative consultancy visits to Ethiopia and Kenya by experienced stem rust pathologists from the University of Sydney and the Free State University, 2) visits by mid-career staff from EIAR and KARI to the stem rust laboratories at the University of Sydney and the Free State University, and 3) inter-continental travel to visit ARI colleagues for three EIAR and two KARI scientists each year.

This Objective will be designed to service the entire world, but East African farmers and consumers will be direct and early beneficiaries since the targeted capabilities and activities will be aligned with the specialized needs of both Kenya and Ethiopia.

Objective 5. Breeding (Conventional and Molecular) to Produce Rust Resistant Wheat Varieties

The best control strategy of rust diseases of wheat for resource poor farmers in the developing world—and the most environmentally friendly and profitable strategy for commercial farmers everywhere—is to grow genetically resistant varieties. The cost of protecting one hectare of wheat from rust epidemics through modern chemicals can range from US$ 50-80. Cultivation of publicly owned resistant wheat varieties has no additional cost to farmers and has succeeded in reduced chemical use across about two-thirds of the 215 million hectares sown to wheat worldwide. Use of resistant varieties thus increases profit margins, helps keep the price of staple crops at affordable levels, and has a beneficial effect on human and environmental health, given that fewer agrochemicals are applied to the crop. Improved varieties are also vehicles to enhance farmers' profitability by delivering new scientific innovations as a package of various genetically controlled desirable traits such as higher yield ability, water and nutrient use efficiency, tolerance to heat and other stresses, and end-use quality characteristics. A small group of improved breeding lines of wheat with diverse sources of both race-specific (major-gene-based) and complex adult-plant (minor-gene-based) resistance to the Ug99 race of stem rust, identified recently through rigorous field and greenhouse testing, can now be employed in developing and delivering wheat cultivars with durable resistance and other desired characteristics.

The following two strategic approaches will be used to combat the threat of stem rust: 1) breeding wheat cultivars that have minor-gene adult plant resistance for high risk areas of East Africa and for production areas in the Ug99 migration path to avoid further breakdown of resistance through the accumulation of additional virulences for race-specific genes and 2) breeding race-specific resistance major genes into targeted varieties and promising new wheat materials in secondary risk areas. The race-specific resistance major genes will be used in combinations of two or more to enhance their longevity. This strategy can be applied for genes that have not been used previously. The above two approaches are necessary due to the current status of resistance in the adapted germplasm and cultivars that will be used for breeding. This approach will also enhance the level of genetic diversity for resistance within and between different epidemiologic zones.

Approach 1 will be accomplished through an accelerated shuttle breeding program to grow wheat breeding materials twice per year at key field sites; this enables intense selection pressure for all three rusts and other important diseases and pests together with adaptation related traits (photoperiod and vernalization response, days to maturity, etc), yield potential, and tolerance to drought and heat stress. Some of the early segregating generations will be exposed to high stem rust pressure at critical field sites in East Africa to enhance the frequency of Ug99 resistant advanced lines. Final confirmation of resistance will be made by testing advanced lines at least twice in East Africa while characterizing the yield potential and determining tolerance to other abiotic stresses. For Approach 2, marker-assisted selection will be employed to transfer currently effective resistance genes with known markers in important cultivars and new elite wheat lines that have potential to become cultivars in the future. Once new genes, not already used previously, become available, they will be incorporated in combinations.

Races of stem rust, different from Ug99, with virulence for resistance genes in durum wheats occur principally in Ethiopia, where durum wheat is grown in marginal areas by mostly resource poor farmers especially to avoid the risk of major stem rust epidemics that are more common in areas with moderate to high rainfall or irrigation. Knowledge of resistance to stem rust in durum wheat is limited at present and resistance to Ethiopian races is known to be present in few land races, old tall and semi-dwarf varieties.

Considering the diverse ecology and type of wheats grown in the principal risk areas along the migration path of Ug99 and secondary risk areas of developing countries, the objective will be met by eight breeding activities to focus each target environment. Breeding and testing will be done by CIMMYT and ICARDA in collaboration with various National Programs that are close collaborators.

Objective Activities will be targeted to address the needs of developing countries under immediate risk along the predicted migration path of Ug99, as well as other secondary risk areas where the unpredicted introduction of Ug99 may cause severe losses affecting local as well as global food security and livelihoods.

Outcomes (near and longer term)

1. Local, national, regional and global food security ensured.
2. Serious losses from Ug99 race of stem rust pathogen and other rust diseases averted through the cultivation of genetically resistant wheat varieties.
3. Negative impacts on livelihoods of resource poor farmers from rust epidemics thwarted.
4. Excessive use of agrochemicals (fungicides) with negative impacts on environment and human health avoided.
5. Wheat productivity and income enhanced by growing new wheat varieties that have higher yield potential, stress tolerance and improved end use quality characteristics.
6. New wheat germplasm with enhanced genetic diversity and breeding methodologies used by National Programs and International Centers will help sustain long-term productivity of wheat based cropping systems.

The breeding program will be a large multi-national and multi-institutional effort that will take advantage of all of the outputs developed by the other proposed objectives. It is also the most expensive single activity, taking up almost 25% of the proposed project budget. Success of the program will be a function of this team working closely with all the other teams. It will likely be year two before the first new rust resistant varieties will be available and probably five years before the varieties are widely adopted by growers. During this time frame, efforts will be made to assure that a workable seed multiplication and distribution system is place in all the affected countries. This will be important for quick adoption of the new varieties.

Objective 6. Developing and Optimizing Markers for Rust Resistance

A large number of inexpensive markers are necessary for mapping and cloning of genes linked to economically important traits and for implementation of efficient breeding methods for rapid development of rust resistant varieties. Multiple major genes can be combined (pyramided) most efficiently if molecular markers are available for each of them. Markers are also essential for identifying varieties that possess novel resistance alleles. In addition, they minimize the risk of spending time and money on searching for a redundant resistance gene that could have been derived unknowingly from a known source. Single-nucleotide polymorphism (SNP) markers have become the technology of choice for most organisms because of their high frequency, wide distribution in genomes, and adaptation to high multiplex detection systems. However, there are not enough SNP markers available for wheat. Consequently, this project will use a combination of microsatellite (SSR), sequence tagged site (STS), and Diversity Array Technology (DArT) markers for haplotyping, pyramiding, and mapping stem rust resistance genes.

For this Objective, it is proposed that current technologies and resources be used to facilitate the development and optimization of markers for stem rust resistance genes in the shortest possible time frame. Our primary goal is to identify robust markers for previously characterized and novel sources of stem rust resistance. This objective can be partitioned into four sub-objectives: 1) optimization of markers for previously characterized stem rust resistance genes; 2) haplotyping uncharacterized rust resistant genotypes to infer novelty and to plan new mapping experiments; 3) pyramiding novel sources of rust resistance; and 4) mapping novel sources of rust resistance. The collaborating labs will work synergistically on these sub-objectives to develop the resources for deploying Ug99 stem rust resistance in superior varieties. Targets include both major gene and minor gene based resistances.

The activities associated with this Objective will be coordinated and integrated with the rest of the project to prioritize the sources of resistance, the varieties to be improved, the breeding strategies, and deployment of improved varieties. This project will have direct linkages to Objective 5 (conventional and molecular breeding to produce rust resistant replacement wheat varieties), 8 (discovering new sources of rust resistance in wild wheat and barley), and Objective 7 (separating useful resistance genes away from deleterious linkage drag).

Objective 7. Reducing Linkage Drag Associated with Rust Resistance Genes

Cultivated wheat has a large number of related species and genera that represent an invaluable gene pool for wheat improvement. In the past 50 years, a number of effective stem rust (Sr) resistance genes identified from wild relatives of wheat have been incorporated into the wheat genome through genetic manipulation in the form of chromosome translocations and additions. Some of these genes, including *Sr25*, *Sr26*, and *Sr43* from *Thinopyrum elongatum*, *Sr37* and *Sr40* from *Triticum timopheevii*, *Sr32* and *Sr39* from *Aegilops speltoides*, and *Sr44* from *Th. intermedium*, have been found to be effective against Ug99. In addition, three novel Sr genes have been identified recently (temporally designated as *Sr2S*, *Sr5S*, and *Sr6V*) from *Ae. speltoides* and *Haynaldia villosa*. Deployment of combinations of these Sr genes in wheat can provide protection against the various races of the stem rust fungus, including Ug99. However, except for *Sr25* and *Sr26*, all the other genes on the alien segments are associated with undesirable agronomic characteristics due to deleterious linkage drag. In addition, some of the available wheat lines containing these resistance genes are not genetically stable because large amounts of alien genetic materials have been integrated into these lines. These Sr resistance genes are not useful in their current forms.

Thus, the purpose of this Objective is to separate deleterious linkage drag from the Sr genes including *Sr32, Sr37*, *Sr39, Sr40, Sr43*, *Sr44*, *Sr2S*, *Sr5S*, and *Sr6V* to eliminate unwanted alien genetic materials. To remove unwanted alien DNA segments, homoeologous recombination will be induced by crossing and backcrossing the original translocation or addition lines carrying the Sr genes with the *Ph1* (pairing homoeologous) gene mutant (*ph1b*) and *Ph1*-deficienct aneuploids susceptible to stem rust. Resultant progeny plants with reduced alien DNA segments will be selected via stem rust resistance testing, molecular markers, and fluorescent genomic *in* *situ* hybridization (FGISH). It is expected that useful genetic stocks carrying each of the nine Sr genes will be developed and available for further germplasm enhancement efforts or immediately useful for breeding during the first 3-year funding period. At least four wheat lines in which the alien DNA segment carrying each of the Sr genes *Sr32, Sr37, Sr39,* and *Sr40* is reduced to a minimal level will be developed. The Sr genes on the shortened translocations will be delivered to the wheat breeders to develop elite wheat germplasm with durable resistance to stem rust.

Objective 8. Discovering New Sources of Rust Resistance in Wild Wheat and Wild Barley

Ug99 and its derivatives possess virulence combinations that are capable of overcoming most of the 50+ major stem rust resistance genes available in wheat, including those most commonly used in major varieties throughout the world. Of the few major genes that remain effective against Ug99 in wheat, most were introduced from related species by inter-specific hybridizations. For durum wheat, an estimated 70% of CIMMYT and ICARDA, and 50% of North American advanced lines and varieties are susceptible to Ug99. Additional virulences specific to durum wheat are found in Ethiopia, rendering that crop's vulnerability to stem rust even higher. Stem rust resistance in cultivated barley is very limited in general. Thus, identifying new sources of resistance to Ug99 is a top priority. Most of the phenotyping of wheat (common and durum) and barley conducted to date has focused on advanced breeding lines, varieties, and special genetic stocks carrying known genes. This Objective expands the search for resistance into the wealth of genetic diversity in wild relatives preserved in gene banks. Work to initiate or expand efforts to introgress resistance genes discovered in diploid wild relatives will also be initiated or expanded.

Because the majority of Ug99-effective major genes are derived from relatives of common and durum wheat, it is logical to extend the search for new resistances to those gene pools. Preliminary experiments at the Cereal Disease Laboratory have shown that resistance to Ug99 in *Aegilops speltoides*, *Triticum timopheevi* and *Ae. sharonensis* is common and that many accessions exhibited near-immune reactions. Resistance to Ug99 also was observed in *Hordeum vulgare* subsp. *spontaneum*. Identifying resistance in close relatives of these crop species will likely produce novel genes. The goal of this Objective is to discover new sources of resistance to Ug99 in wild relatives of common wheat, durum wheat, and barley. This will be accomplished by targeted, systematic phenotyping of wild relative accessions held in the gene banks.

This Objective will therefore include seedling assay phenotyping of gene bank accessions of several wild relatives of wheat, including *Triticum monococcum, T. dicoccoides, T. dicoccum, T. carthlicum, T. polonicum, T. timopheevii, Aegilops speltoides, Ae. sharonensis*, and *Ae. tauschii*. Accessions of wild relatives of barley, including *Hordeum vulgare* subsp. *spontaneum* and *H. bulbosum* will also be subjected to seedling tests. Initial screening of wild relatives will be done with Ug99. Resistant accessions will be tested for seedling reaction to other races as the first step in establishing the uniqueness of any major gene resistances. Work to transfer (introgress) putatively new resistance genes from the wild diploids will be initiated or expanded. Adult-plant screening of wild tetraploid species from ICARDA's gene bank will also be conducted using the Critical Facility site in Ethiopia.

Outputs (deliverables) of this Objective will be the discovery of accessions of wild relatives of wheat and barley carrying putatively novel resistance genes and of wheat and barley lines carrying the newly discovered genes (from diploid species). All data will be registered with the originating gene bank and made available on the Project Website. The identity and nature of accessions exhibiting resistance will be pro-actively disseminated to the research community. The project will promote follow-on activities by non-project and project partners to: a) further elaboration of the genetic basis of resistance, including where appropriate development of diagnostic markers; and complete transfer of resistance into agronomically elite wheat and barley varieties and breeding lines. The outcome (impact) of this Objective will be increased diversity for stem rust resistance genes, greater durability of resistance in deployed cultivars, and ultimately more sustainable cereal cropping systems for the resource poor.

Objective 9. Exploring Rice Immunity to Rust

Rust diseases are common in cereals, yet rice is not affected by the entire taxa of rust fungi. It is hypothesized that rice possesses non-host resistance (NHR) that confers complete resistance. Although NHR is the norm in plant-microbe interactions, the molecular basis of NHR is not well understood. Recent advances in Arabidopsis/powdery mildew interactions have demonstrated that NHR is not as genetically complex or intractable as initially thought, raising the possibility that NHR genes can be transferred between species. This component of the proposal aims to identify rice mutants and selected germplasm compromised in NHR to wheat rust fungi, so that rice rust resistance genes can be isolated and introduced into wheat.

Exploratory studies on the infection process of stem rust on rice show that development of rust infection structures does occur on rice, which is an essential pre-requisite for plant colonization. Rice is observed to respond by formation of callose and autofluorescent compounds, suggestive of an active defense response. Furthermore, in a preliminary screen of rice germplasm with stem rust, several rice lines exhibited distinct fleck reactions, suggesting that it is possible to detect stem rust infection macroscopically and to develop a high-throughput screening for a variety of mutant phenotypes. These observations together suggest that cereal rust can infect rice and implicate an active, genetically defined NHR response and that heritable changes can be identified to enable genetic dissection of rust immunity in rice. A research team has been assembled that has complementary expertise in plant genetics, rust pathology, and molecular biology. The team has a large collection of rice mutants and germplasm for systematic screening of rice-rust interaction at micro- and macro-levels. Over 20,000 mutant lines and 3,000 rice germplasm accessions will be screened for altered response to multiple rust and rice pathogens. The use of multiple pathogens in disease evaluation is important to ensure that the genes identified can eventually contribute to broad-spectrum resistance in wheat. Double or triple mutants will be constructed to identify the essential genes involved in NHR and determine their interactions. Once useful mutations are found, genes of interest will be isolated and validated for function. Efficient methodologies are in place for gene cloning using the T-DNA and deletion mutants.

Objective 10. Project Management

The Durable Rust Resistance in Wheat Project will be administered by the Office of International Programs in the College of Agriculture and Life Sciences (IP/CALS) at Cornell University. IP/CALS is located on the Cornell campus in Ithaca, New York. IP/CALS has extensive experience with donor-funded projects and has its own Project Management Office. IP/CALS's long and successful donor-funded project experience will ensure timely satisfaction of all BMGF reporting requirements.

The Director of IP/CALS, Dr. Ronnie Coffman, will serve as the Principal Investigator and Director for the project and supervise the coordinating staff . Leadership within the Project Objectives will be provided by Team Leaders (or Co-Leaders. Team Leaders will foster coordination among scientists funded through their Objective, and also act as point persons in liaison with the Project Coordinators and outside partners.   In some cases, leadership for an objective may be provided directly by the Project Coordinator or the Associate Coordinator but, normally, scientific leadership (including the coordination of reporting for each objective) will come from among the participants in the objective.

Project Objective (Logframes)

Durable Rust Resistance in Wheat

Objective 1: Planning for the Threat of Emerging Wheat Rust Variants		
Activities	**Outputs**	**Outcomes (Short and Long Term)**
Activity 1.1 Conduct convening on how to promote and exploit advances in pathogen genomics and molecular biology to combat wheat rusts.	• Expert-vetted list of ongoing and needed outcome-oriented research activities prioritized by magnitude and timing of impact. Report posted to project website. • Enhanced communication and cooperation among global actors. • Recruitment of additional players to work on P. graminis • Identification of potential funding sources.	• Breakthroughs in rust resistance/immunity occurred earlier through best science employing pathogen genomics and molecular biology
Activity 1.2 Conduct convening on how to promote and exploit advances in host molecular marker technologies to combat wheat rusts.	• Expert-vetted list of outcome-oriented research activities prioritized by magnitude and timing of impact. Report posted to project website. • Enhanced communication among global actors in the relevant range of disciplines including wheat breeding and genetics, and contemporary molecular marker technologies, with a focus on improving access for breeders to markers that they will use • Identification of potential funding sources. • Agreement on processes leading to submission of funding proposals for SNP development.	• Duplication minimized and synergies maximized among scientists working on marker development and optimization. • Access to critical rust resistance gene markers not limited for breeding programs targeting resource poor farmers. • SNP based markers employed in breeding for resource poor farmers sooner because of research and impact paths identified at convening.
Activity 1.3 Conduct	• Five to seven country-specific wheat seed sector SWOT or	• Solvable problems in at-risk country

country specific consultative planning with at-risk NARS, seed sector actors, regional CG scientists, and donors to identify interventions required to accelerate timing and scale of impact of new rust resistant varieties.	similar analyses generated by independent consultants. Public component posted to project website. Countries: Kenya, Ethiopia, Egypt, Turkey, Iran, Pakistan, India. • For the targeted countries, report of NARS endorsed interventions required to maximize effectiveness of seed sectors, both pre- and post variety release. • Increased international coordination for access and release of wheat varieties resistant to Ug99 and derivatives • Identification of potential funding sources.	Seed Sectors did not retard timing or scope of impact of rust resistant varieties on resource poor farmers.
Activity 1.4 Develop follow-on phase II proposal with broad input from appropriate experts	• Best-science based comprehensive phase II proposal inclusive of phase I components where appropriate plus additional components; including but not limited to ones which focus on seed, socio-economics, information technology, pathogen diagnostics, next-generation molecular markers, and expanded (based on current state of science) activities in non-host resistance. Submission to BMGF June 2009. • Recruitment of all possible matching or in-kind funding. • Recruitment of the world's best experts as cooperators.	• A best-science, highest impact Phase II proposal developed through a process characterized by transparency and inclusiveness.

Objective 2: Advocating and Coordinating Global Awareness and Cooperation		
Activities	**Outputs**	**Outcomes (Short- and Long-Term)**
2.1 Create Advocacy and Coordination Office with comprehensive web-based knowledge base and portal.	• Advocacy and Coordination Office is operational. • Web based knowledge base and portal provides laymen, scientists, and donors/investors with: o User appropriate awareness of the rust problem; o global inventories of research institutions working on wheat rust including ARIs, IARCs, and NARS with information on: ▪ research personnel, ▪ capacities, ▪ projects o Global inventories of donors; both traditional and non-traditional, international, regional, and country-specific; including contact information and priorities. o Global inventories of professional societies and other international advocacy groups o Tools for facilitating communication leading to partnerships and coordinated action. o 'Gap analysis' showing shortfall between actual funding and research and what is needed.	International efforts to grow and sustain coordinated efforts to mitigate and eliminate the rust problem are no longer limited by lack of ready access to comprehensive knowledge and communications.
2.2 Coordinate Project activities and promote linkages with other partners.	• Inter-Objective cooperation is optimal. • Cross project ideas, insights, and discoveries are rapidly translated into action and impact. • Project activities leverage additional investments and partnerships.	Project impact is increased through within project efficiency and leveraged partnerships.
2.3 Advocate for rational, coordinated, and	• Borlaug Global Rust Initiative becomes the global forum for technical and policy. • Pesentations and other communication tools maintained and	Vulnerability to wheat rusts is minimized in the shortest time possible.

sustained global strategies through education outreach and through logistical and other support for the Borlaug Global Rust Initiative.	updated for advocacy at all levels • High profile advocates (e.g. NE Borlaug, key NARS DGs, etc) visit key actors in donor community • detailed background on donor priorities maintained and updated. • Key donor staff are visited by advocacy office personnel or others. • Expanded engagement and investment by multiple stakeholders/Donors/investors in an effective, coordinated response to stem rust. • A rational, coordinated, and sustained global strategy to mitigate and eliminate the threat of rust to wheat	
2.4 Facilitate awareness of the importance of robust policies and strategies for optimized gene deployment.	• Gene deployment is accepted as a critical element of the resiliency of wheat production in the developing world. • Scientific societies and policy makers actively address the issue of alternative gene deployment strateges.	Genetic vulnerability to wheat rusts is lowered leading to increased food and livelihood securities.
2.5 Conduct Special Initiatives (ad hoc gatherings, travel facilitation to critical events, etc)	• Enlarged buy-in or collaboration from NARS, ARIs, Donors, and investors.	Opportunities for advocacy and collaboration not missed.

Objective 3: Tracking Wheat Rust Pathogens

Activities	Outputs	Outcomes (Short and Long Term)
3.1 Develop the information platform underpinning a global rust monitoring system: At the field, national, and global levels standardized protocols, methods & systems put in place for data/sample collection and management	• Standardized protocols and methods for undertaking field surveys (including sampling) and preliminary virulence testing; followed by transmission of data and samples to national & international focal points. • Databases and data management systems at the national and international levels to store and analyze cereal rust data from surveys and follow-on national or international analyses of pathogen and host samples.	Uniform data acquisition and storage protocols are employed for stem rust in a Global Cereal Rust Monitoring System.
3.2 Develop national capacity to undertake effective pathogen tracking and monitoring: Identify and train both field surveyors and national information system managers in cereal rust survey (including sampling) techniques	• NARS staff enabled/organized to contribute geo-referenced survey data and associated samples to international tracking/monitoring system through Baseline Survey Planning Workshop (March 08). • Baseline Survey conducted on 07/08 crop; enabling baseline information on distribution and nature (fingerprint/race/virulence) of stem rust, and where appropriate, R genes in major varieties in target region. • Full survey generated data/samples integrated into Global Cereal Rust Monitoring System in 08/09 and subsequent crops enabling monitoring of distribution and nature (fingerprint/race/virulence) of stem rust, and where appropriate, R genes in major varieties in target region.	National Surveillance Teams are conducting annual surveys using uniform protocols enabling National Focal Point persons to manage data streams contributing to information in a Global Cereal Rust Monitoring System.
3.3 Operationalize and implement a Global Cereal Rust	• A functional global cereal rust monitoring system comprised of an International Focal Point at the FAO	Resource poor farmers have greater food and livelihood

Monitoring System: Transform regular field survey data into targeted dissemination products, through integrated data management and analysis in a spatial framework.	and National Focal Points within NARS is receiving regular field survey data and follow-on quality assured pathogen/host data originating from at least 7 priority countries; undertaking integrated spatial analysis to determine status/nature and likely movements of stem rust populations; and disseminating a range of web-based information products on a quarterly basis.	securities because policy makers and scientists use products of the Global Cereal Rust Monitoring System based at FAO to make informed and timely decisions on research priorities/investments in wheat protection and improvement (including gene deployment).
3.4 Pathogen Race and Host Resistance gene distribution: Establish the current distribution of ‘Ug99’ lineage, monitor spread, examine evolution of virulence and determine implications for current wheat cultivars.	• Pathogen (fingerprint/race/virulences) and host (resistance genes) characteristics of survey samples generated at NARS and ARIs; and integrated into the Global Cereal Rust Monitoring System after vetting moderated by the Coordinating Pathologist at U. of Sydney.	The Global Cereal Rust Monitoring System has up-to-date information on the nature and distribution of stem rust races and wheat rust resistance genes.

Objective 4: Supporting Critical Rust Screening Facilities in East Africa		
Activities	**Outputs**	**Outcomes (Short- and Long-Term)**
Activity 4.1 Expand and coordinate the capacity of KARI and EIAR to accurately phenotype wheat genetic resources for reaction to stem rust Ug99 and derivatives.	Infrastructure, equipment, human resources, and operational protocols established for 1) timely exchanges of information and seed with international partners; and 2) maintainence of and characterization of stem rust isolates from Kenya or Ethiopia; 3) managed epiphytotics induced by inoculum of appropriate pathotypes.	The KARI and EIAR Critical Facilities are fully operational world-class facilities, which are critical-path components of a global wheat improvement effort to defend against Ug99.
Activity 4.2 Conduct common wheat phenotyping at KARI's Njoro Research Center.	Timely return of data on adult plant responses to stem and yellow rusts for breeding and research materials (primarily common wheat), and/or seed of selected progeny.	Breeders and geneticists at KARI, EIAR, CG Centers, Advanced Research Institutes (ARIs), and NARs are able to accelerate and expand efforts to identify, genetically characterize, validate, and deploy new and durable resistances to Ug99 and other rusts. As a result, farmers are growing varieties with durable resistance (including minor gene, Adult Plant Resistances) to rusts. Failure to achieve this objective disables the world’s ability to defend itself against Ug99.

Activity 4.3 Conduct durum wheat phenotyping at EIAR's Debra Zeit Research Center with inoculum generated at EIAR's Ambo station.	Timely return of data on adult plant responses to stem and yellow rusts for breeding and research materials (primarily durum wheat), and/or seed of selected progeny.	Breeders and geneticists at KARI, EIAR, CG Centers, Advanced Research Institutes (ARIs), and NARs are able to accelerate and expand efforts to identify, genetically characterize, validate, and deploy new and durable resistances to Ug99 and other rusts. As a result, farmers are growing varieties with durable resistance (including minor gene, Adult Plant Resistances) to rusts. Failure to achieve this objective disables the world's ability to defend itself against Ug99.
Activity 4.4 Provide in-service learning opportunities for KARI and EIAR staff	KARI and EIAR staff gain contemporary skills in pathotyping, field scoring, pathogen management, and IWIS data management system; KARI and EIAR scientists participate in International meetings.	Scientists and staff at critical facilities in Kenya and Ethiopia possess skill sets enabling publication quality data collection, and data management in IWIS.

Objective 5: Breeding (Conventional and Molecular) to Produce Rust Resistant Wheat Varieties		
Activities	**Outputs**	**Outcomes (Short- and Long-Term)**
Activity 5.1 Spring bread wheat varieties for irrigated and high production environments of Africa, Middle East, West, Central and South Asia developed by the Irrigated Spring Bread Wheat Improvement Program, CIMMYT, Mexico.	• 30–50 high yielding, rust resistant potential replacement varieties tested annually in replicated yield trials in various countries at 50+ field sites. • 100–150 additional high yielding, multiple rust resistant lines distributed annually for evaluation and selection as small plots at over 100 sites worldwide. • About 10 new multiple rust resistant varieties with >5% higher yield potential than current cultivars released officially in various countries by years 3 and 4. • Application of appropriate breeding methodology and use of germplasm with durable resistance promoted for NARS breeding program. • Strong partnerships built for a fast release and promotion of new stem rust resistant cultivars.	1. Food security in spring wheat irrigated and high production environments of Africa, Middle East and Asia ensured. 2. Serious losses from Ug99 race of stem rust pathogen and other rust diseases averted through the cultivation of genetically resistant wheat varieties. 3. Negative impacts on livelihoods of farmers, especially the resource poor, from rust epidemics thwarted. 4. Reduced use of agrochemicals (fungicides) with associated negative impacts on environmental and human health avoided. 5. Wheat productivity and income enhanced by growing new wheat varieties that have higher yield potential, better stress tolerance and improved end-use quality characteristics. 6. New wheat germplasm with enhanced genetic diversity and breeding methodologies used by National Programs and IARCs help sustain long-term productivity of wheat based cropping systems.
Activity 5.2 Spring bread wheat varieties for drought-stressed and low production environments of Africa, Middle East, West, Central and South Asia developed by the Rainfed Spring Wheat	• At least 5–10 lines sent every year (from year 1) to NARS coming from rainfed international trials and screening nurseries with good yield potential, tolerance to drought and resistance to yellow rust, leaf rust and Ug99 stem rust.	1. Food security in spring wheat low production environments of Africa, Middle East and Asia ensured. 2. Serious losses from Ug99 race of stem rust pathogen and other rust diseases averted through the cultivation of genetically resistant wheat varieties. 3. Negative impacts on livelihoods of farmers, especially

Improvement Program, CIMMYT, Mexico.	• At least 70 lines sent to NARS at the end of year 6 with good yield potential, tolerance to drought, resistance to yellow rust, leaf rust and Ug99 stem rust, and resistance to biotic and abiotic soil stresses. • 3–4 stem rust resistant varieties selected for release by NARS by year 4	the resource poor, from rust epidemics thwarted. 4. Wheat productivity and income enhanced by growing new wheat varieties that have higher yield potential, better stress tolerance and improved end use quality characteristics. 5. New wheat germplasm with enhanced genetic diversity and breeding methodologies used by National Programs and IARCs help sustain long-term productivity of wheat based cropping systems.
Activity 5.3 Spring bread wheat varieties for diverse production environments of CWANA region developed by Spring Bread Wheat Improvement Program, ICARDA, Syria.	• 4–5 new varieties released by NARS by year 3 from existing resistant materials *ex* CIMMYT/ICARDA. • About 30 high yielding lines with resistance to stem rust distributed to NARS in CWANA region in year 6 as replicated yield trials. • About 100 high yielding lines with resistance to stem rust distributed to NARS in CWANA region in year 6 as screening nurseries.	1. Food security in diverse spring wheat production environments of CWANA region ensured. 2. Serious losses from Ug99 race of stem rust pathogen and other rust diseases averted through the cultivation of genetically resistant wheat varieties. 3. Negative impacts on livelihoods of farmers, especially the resource poor, from rust epidemics thwarted. 4. Excessive use of agrochemicals (fungicides) with negative impacts on environment and human health avoided. 5. Wheat productivity and income enhanced by growing new wheat varieties that have higher yield potential, better stress tolerance and improved end use quality characteristics. 6. New wheat germplasm with enhanced genetic diversity and breeding methodologies used by National Programs and IARCs help sustain long-term productivity of wheat based cropping systems.
Activity 5.4 Developing and delivering stem rust resistant facultative and winter bread	• At least 30 winter and facultative wheat lines combining resistance to Ug99 and other diseases targeted to	1. Food security in diverse facultative and winter wheat production environments of CWANA region ensured. 2. Serious losses from Ug99 race of stem rust pathogen

wheat varieties for CWANA region.	irrigated and rainfed conditions of CWANA are sent to cooperators in NARS • 2-3 new varieties submitted for official testing by the NARS to replace the varieties susceptible to Ug99	and other rust diseases averted through the cultivation of genetically resistant wheat varieties. 3. Negative impacts on livelihoods of farmers, especially the resource poor, from rust epidemics thwarted. 4. Excessive use of agrochemicals (fungicides) with negative impacts on environment and human health avoided. 5. Wheat productivity and income enhanced by growing new wheat varieties that have higher yield potential, better stress tolerance and improved end use quality characteristics. 6. New wheat germplasm with enhanced genetic diversity and breeding methodologies used by National Programs and International Centers help sustain long-term productivity of wheat based cropping systems.
Activity 5.5 Developing and delivering stem rust resistant photosensitive spring bread wheat varieties for Central Asia.	• 100–200 lines available at the end of year 4 with resistance to Ug99 based on major genes, resistance to leaf rust, good adaptation to Northern Kazakhstan, available to local breeding programs for testing and use in crossing. • 2–5 varieties identified at the end of year 7 with resistance to Ug99, and potential to replace current varieties in Northern Kazakhstan.	1. Food security in photosensitive wheat production environments of Central Asia ensured. 2. Serious losses from Ug99 race of stem rust pathogen and other rust diseases averted through the cultivation of genetically resistant wheat varieties. 3. Wheat productivity and income enhanced by growing new wheat varieties that have higher yield potential, better stress tolerance and improved end use quality characteristics. 4. New wheat germplasm with enhanced genetic diversity and breeding methodologies used by National Programs and International Centers help sustain long-term productivity of wheat based cropping systems.
Activity 5.6 Developing and delivering stem rust resistant spring, facultative and winter bread wheat varieties	• 30–40 advanced lines with high yield potential, resistance to Ug99 and other diseases will be developed. • 5–8 varieties with high yield	1. Food security in diverse wheat production environments of China ensured. 2. Serious losses from Ug99 race of stem rust and other rust diseases averted through the cultivation of

for China.	potential, good quality, and resistance to UG99 will be released at provincial levels.	genetically resistant wheat varieties. 3. Negative impacts on livelihoods of farmers, especially the resource poor, from rust epidemics thwarted. 4. Use of agrochemicals (fungicides) with negative impacts on environment and human health avoided. 5. Wheat productivity and income enhanced by growing new wheat varieties that have higher yield potential, better stress tolerance and improved end use quality characteristics. 6. New wheat germplasm with enhanced genetic diversity and breeding methodologies used by National Programs and IARCs help sustain long-term productivity of wheat based cropping systems.
Activity 5.7 Durum wheat varieties for Africa, Middle East, Asia and Latin America by Durum Wheat Improvement Program, CIMMYT, Mexico.	• 2–3 stem rust resistant varieties for release in Ethiopia by year 5. • 20–30 stem rust resistant durum lines with >5% higher yields than current varieties distributed worldwide in year 5 for yield testing. • About 50 additional high yielding, stem rust resistant durum lines distributed worldwide in CIMMYT screening nurseries.	1. Food security in durum wheat production environments of Africa, Middle East, Asia and Latin America ensured. 2. Serious losses from Ug99 race of stem rust and other rust diseases averted through the cultivation of genetically resistant wheat varieties. 3. Negative impacts on livelihoods of farmers, especially the resource poor, from rust epidemics thwarted. 4. Wheat productivity and income enhanced by growing new wheat varieties that have higher yield potential, better stress tolerance and improved end use quality characteristics. 5. New wheat germplasm with enhanced genetic diversity and breeding methodologies used by National Programs and IARCs help sustain long-term productivity of wheat based cropping systems.

Activity 5.8 Durum wheat varieties for CWANA by Durum Wheat Improvement Program, ICARDA, Syria.	• 20–30 potential stem rust resistant varieties with >5% higher yield potential than current cultivars in year 4 and 5 distributed for testing by NARS in replicated yield trials. • About 100 additional stem rust resistant durum lines developed and distributed in small seed quantities by year 4 and 5. • At least 2 stem rust resistant durum varieties identified for release in Ethiopia by year 5.	1. Food security in durum wheat production environments of CWANA region assured. 2. Serious losses from Ug99 race of stem rust and other rust diseases averted through the cultivation of genetically resistant wheat varieties. 3. Negative impacts on livelihoods of farmers, especially the resource poor, from rust epidemics thwarted. 4. Wheat productivity and income enhanced by growing new wheat varieties that have higher yield potential, better stress tolerance and improved end use quality characteristics. 5. New wheat germplasm with enhanced genetic diversity and breeding methodologies used by National Programs and IARCs help sustain long-term productivity of wheat based cropping systems.

Objective 6: Developing and Optimizing Markers For Rust Resistance

Activities	Outputs	Outcomes (Short- and Long-Term)
Activity 6.1 Optimization of markers for previously characterized rust resistance gene markers	Optimized markers for all genes from the primary gene pool providing effective stem rust resistance to maximize efficiency of the breeding program.	*Short Term:* Materials and information necessary for marker-assisted breeding. *Long Term:* Resources necessary for pyramiding rust genes for durable resistance.
Activity 6.2 Haplotyping uncharacterized rust resistant genotypes to infer novelty and to plan new mapping experiments	Haplotypes for major resistance loci of uncharacterized sources of stem rust resistance. Genetic relationship estimates among all uncharacterized sources of stem rust resistance.	*Short Term:* Information required for cross-referencing sources of rust resistance. *Long Term:* A catalog of all known sources of marker alleles linked to rust resistance genes
Activity 6.3 Pyramiding novel sources of rust resistance	Several different breeding populations homozygous for 2 or more stem rust resistance genes.	*Short Term:* Molecular markers for new sources of rust resistance for use in the breeding programs. *Long Term:* Resources necessary for developing varieties with durable quantitative rust resistance.
Activity 6.4 Mapping novel sources of rust resistance	Mapped QTL for new sources of rust resistance including newly identified sources as well as APR in 4 to 6 different mapping populations	*Short Term:* Molecular markers for new sources of rust resistance for use in the breeding programs. *Long Term:* Resources necessary for developing varieties with durable quantitative rust resistance.

Objective 7: Reducing Linkage Drag Associated with Rust Resistance Genes

Activities	Outputs	Outcomes (Short- and Long-Term)
Activity 7.1 Separate Sr37, Sr39, Sr43, and Sr2BS from linkage drag and combine two resistance genes into a single linkage block	Two wheat germplasm lines each carrying the genes Sr37 and Sr39 on shortened alien chromosome segments. Improved genetic stocks with Sr43 and Sr2BS. Molecular markers closely linked to the Sr37 and Sr39. New and improved protocols and techniques for alien gene introgression.	*Short term:* Wheat germplasm lines each carrying the genes Sr37, Sr39, Sr43, and Sr2BS on shortened alien chromosome segments are available for breeding cultivars with durable stem rust resistance. *Long term:* Elite wheat lines carrying the genes Sr37, Sr39, Sr43, and Sr2BS are available for testing yield, quality, and stem rust resistance in the target regions.
Activity 7.2 Separate Sr32, Sr40, Sr44, Sr6V, and Sr5S from linkage drag	Genetic stocks carrying Sr32 and Sr40 on shortened alien chromosome segments. Compensating translocation lines with Sr44, Sr6V, and Sr5S. New and improved protocols and techniques for alien gene introgression.	*Short term*: Improved germplasm lines carrying the genes Sr32, Sr40, Sr44, Sr6V, and Sr5S are available for breeding cultivars with durable stem rust resistance. *Long term:* Enhanced diversity of agronomically acceptable sources of stem rust resistance.
Activity 7.3 Evaluate parental lines, segregation populations, and new translocation lines for reactions to stem rust	Evaluation data of parental lines, segregation populations, and new translocation lines for reactions to multiple pathotypes of stem rust.	The outcomes of this Activity are the same as those of Activities 7.1 and 7.2 because it provides the rust testing needed in the Activities 7.1 and 7.2.

Objective 8: Discovering New Sources of Rust Resistance in Wild Wheat and Wild Barley

Activities	Outputs	Outcomes (Short- and Long-Term)
Activity 8.1 Screening wild relatives of wheat and durum at the seedling stage with race Ug99	The presence and prevalence of Ug99 resistance in the targeted species, as well as specific accessions, of wild relatives of wheat and durum are known	Specific accessions of wild relatives are served as the targets for introgressing novel resistance genes into wheat and durum. Stem rust resistance gene pools of wheat and durum are enriched.
Activity 8.2 Screening wild relatives of barley at the seedling stage with Ug99	The presence and prevalence of Ug99 resistance in the targeted species of wild relatives of barley are known	Specific accessions of wild relatives are served as the targets for introgressing novel resistance genes into barley. Stem rust resistance gene pool of barley is enriched
Activity 8.3 Screening of ICARDA collection of wild tetraploids under field conditions for adult plant resistance to Ug99 at Debre Zeit, Ethiopia	Tetraploid wild relatives of wheat identified with novel sources adult plant resistance to Ug99; results posted to project website; resistant selections available to global community	Useful accessions of tetraploid wild relatives of wheat with adult plant resistance to Ug99 identified for use in bread and durum wheat breeding. Knowledge and availability of resistance germplasm pool enhanced
Activity 8.4 Introgressing resistance from *T. timopheevii* and *Ae. speltoides* to wheat	Genetic stocks homozygous for Ug99 resistance are produced from >20 accessions of wild wheat relatives.	Potentially new sources of resistance for use in breeding and germplasm enhancement. Diversity of wheat stem rust resistance is enriched.
Activity 8.5 Introgressing resistance from *Ae. sharonensis* to wheat	Genes conferring resistance to Ug99 in *Aegilops sharonensis* are introgressed into genetically stable and agronomically advanced lines of wheat	Stable introgression of Ug99 resistance is completed in agronomically advanced lines of wheat. Resistance to Ug99 in wheat is broadened, resulting in stable production without the need for fungicide applications.
Activity 8.6 Introgressing resistance from wild barley and landraces to barley	Genes conferring resistance to Ug99 in wild barley are introgressed into agronomically advanced breeding lines	Stable introgression of Ug99 resistance is completed in agronomically advanced lines of barley. Resistance to Ug99 in barley is broadened, resulting in stable production without the need for fungicide applications.

Objective 9: Exploring Rice Immunity to Rust

Activities	Outputs	Outcomes (Short- and Long-Term)
Activity 9.1 Establish a panel of stem rust isolates for screening rice mutants. About 25-30 isolates of stem rust fungi (Puccinia graminis (P.g.) tritici, P.g. avenae, P.g. secalis, P.g. phleum, P.g. poae, P.g. festucae) will be propagated and increased for mass screening of rice lines. Collection will be actively maintained for duration of project.	A reference collection representing diversity of P. graminis is actively maintained for screening at multiple stages of the project.	*Short term:* A standardized collection of isolates for assessing rust interaction with wheat and rice
Activity 9.2 High throughput preliminary screening of rice mutants and rice collections (cultivated, landrace, and wild accessions) with a bulk of rust isolates. Establish proper conditions for inoculating rice plants with rust; develop a high-throughput scoring (visual) to differentiate altered response to rust; screen populations.	Standardized and efficient screening procedures established for evaluating rust-rice interactions; rice mutants and selected lines with altered response to rust identified	*Short term:* efficient screen for rust/rice interaction established; feasibility of detecting interaction phenotypes between rice mutants and rust fungi
Activity 9.3 Develop a HTP microscopic analysis technique for altered response to rust infection in relevant rice mutant populations. Apply microscopic screening of rice response to rust fungi; determine critical parameters for interactions, correlate micro- with macro-phenotypes to establish a HTP screen.	Standardized microscopic protocols to evaluate rust-rice interactions; detailed description of rust fungal colonization on rice (wild type and mutants).	*Short term:* Frequency of detecting rust-response mutations in rice known; decision point on whether additional screening is warranted
Activity 9.4 HTP screening for loss-of-resistance to rice pathogens. Combine multiple mutations to increase the likelihood of detecting rust response mutants. Screen 10,000 rice lines for enhanced susceptibility to blast infection; pre-select lines for detailed phenotyping with rust; create double or triple mutants; provide materials for detailed phenotyping	A sub-collection of rice mutants (>50) with altered defense mechanisms; series of double or multiple mutations created for elucidating genetic control of immunity.	*Short-term:* mutants for genetic and pathological analyses

with rust pathogens under 9.2 and 9.3.		
Activity 9.5 Detailed phenotypic evaluation of selected mutants with multiple rust fungi and races including Ug99. Characterize pathologically and physiologically the basis of enhanced infection in selected mutants and rice lines.	Documented interaction between rust fungi and mutants or selected germplasm; phenotypic basis for immunity response understood.	*Short term:* physiological understanding of rust immunity in rice
Activity 9.6 Genetically characterize populations of rice that segregate for stem rust reaction. Construct genetic crosses to determine the genetic control of rust immunity reaction in rice; map mutations conferring loss of resistance in mapping population	Genetic loci controlling reaction to rust determined in rice; genetic basis of immunity established	*Short term:* feasibility of finding rice genes for non-host resistance in wheat determined
Activity 9.7 Determine the spectrum of altered response to multiple pathogens (panel of rust fungi and rice pathogens). Assess rice mutants against an array of rust fungi and rice pathogens.	A set of rice mutants/lines affecting broad-spectrum resistance available	*Short term:* the relationship between non-host resistance and broad-spectrum resistance determined; indicator of potential effectiveness of non-host resistance for wheat rust
Activity 9.8 Chip-based mapping and positional cloning. Phenotypically confirmed mutants or genetic segregates will be scanned with whole-genome gene chips to determine the locations of genetic lesions responsible for the altered response to rust	Genes and narrow chromosomal regions contributing to rust response identified	*Short term:* panel of non-host resistance genes and genomic regions available for testing. Long term: genes for rust resistance proven useful in wheat
Activity 9.9 Isolate T-DNA tagged rust-susceptible mutants and gene identification by co-segregation analysis. Screen collection of T-DNA insertion lines with stripe rust in China; determine co-segregations between T-DNA insertions and rust response phenotypes; create double mutants as needed for detailed phenotypic characterization with multiple rust pathogens (in Activities 9.5 and 9.7).	Tagged mutants available for detailed phenotypic characterization; known genes responsible for rust response	*Short term:* non-host resistance genes available for testing

Objective 10: Project Management

Activities	Outputs	Outcomes (Short- and Long-Term)
Activity 10.1 Establish project management unit	Staff hired; Program and financial management systems established and implemented	Overall program coordination and management; Leadership for advocacy efforts and liaison with BMGF; Appropriate and accessible financial and management reports.
Activity 10.2 Negotiate subcontracts and assess implementation at periodic intervals	International subcontracts negotiated and task orders issued; Quality assured through periodic assessment.	Project subcontractors in place with directives;
Activity 10.3 Programmatic development	EPAC identified; Meeting held in Australia with Activity Leaders; Second-phase proposal developed and completed (in support of Objective 1); Advocacy plan developed and implemented (in support of Objective 2).	Program developed and implemented with input from scientific and activity leaders.
Activity 10.4 Project management	Management website online; Annual report submitted for period January – September 2008; Annual report submitted for period October 2008 – September 2009; Annual meeting.	Project progress and outputs communicated to stakeholders.

Activity 10.5 Special Initiatives	Gender strategy developed by consultant outlining opportunities across the project for the engagement of women is agreed by Cornell and BMGF program officer; Roadmap in place for strengthening Ethiopia's wheat improvement and seed sector for rapid upgrade of Ethiopian wheat to varieties with multi-genic resistance	Within 10 years Ethiopia has an efficient variety replacement system benefiting all wheat growers, losses to stem rust are minimal; The process and outcomes of this project had positive effects on gender issues in development

Legend to Institution-Unit Abbreviations

Abbreviation	Full Name
AAFC	Agriculture and Agri-Foods Canada
CIMMYT-Bejing	CIMMYT Global Wheat Program, Regional Office - Beijing, PRC
CIMMYT-HQ	CIMMYT Global Wheat Program, HQ
CIMMYT-Kenya	CIMMYT Global Wheat Program, Regional Office - Kenya
CIMMYT-KZ	CIMMYT Global Wheat Program, Regional Office - Kenya
Cornell-IP	Cornell International Programs
Cornell-PBG	Cornell Department of Plant Breeding and Genetics
CSIRO-HQ	Australian Commonwealth Scientific and Industrial Research Organisation Plant Industry, Headquarters, Canberra
EIAR-Ambo	Ethiopian Institute of Agriculture Research, Plant Protection Research Center, Ambo
EIAR-HQ	Ethiopian Institute of Agriculture Research, Headquarters, Addis Ababa
ICARDA-HQ	International Center for Agriculture Research in Dry Areas, Headquarters, Syria
IRRI-HQ	International Rice Research Institute, Headquarters, Phillipines
KARI-Njoro	Kenya Agriculture Research Institute, National Plant Breeding Research Center, Njoro Kenya
UC Davis	University of California, Davis
U of Free State	University of Free State, South Africa
U of MN-PB	University of Minnesota, Department of Agronomy and Plant Genetics
U of MN-PP	University of Minnesota, Department of Plant Pathology
U of Sydney-HQ	University of Sydney, Plant Breeding Institute, Australia
UN-FAO-HQ	Food and Agriculture Organization of the United Nations, Plant Production and Protection Division, Italy
USDA-KS	United States Department of Agriculture, Agriculture Research Service, Plant Science and Entomology Research Unit, Kansas
USDA-MN	United States Department of Agriculture, Agriculture Research Service, Cereal Disease Laboratory, Minnesota

DRRW: Project Milestones

Objective	Activity	Milestone	target_date	inst and unit
01 Planning for the Threat of Emerging Wheat Rust Variants	01.1 Conduct convening on how to promote and exploit advances in pathogen genomics and molecular biology to combat wheat rusts.	01.1.01 Symposium on how to promote and exploit advances in pathogen genomics and molecular biology to combat wheat rusts; tracking included.	Jul-08	Cornell-IP
	01.2 Conduct convening on how to promote and exploit advances in host molecular marker technologies to combat wheat rusts.	01.2.01 Convening on how to promote and exploit advances in host molecular marker technologies to combat wheat rusts	Aug-08	Cornell-IP
	01.3 Conduct country specific consultative planning with at-risk NARS, seed sector actors, regional CG scientists, and donors to identify interventions required to accelerate timing and scale of impact of new rust resistant varieties.	01.3.01 Workshop on rust resistance breeding strategies	Oct-08	Cornell-IP
		01.3.02 Meeting to identify policy, logistical, or other barriers to minimizing the time from identification of new varieties to the time of their impact in farm fields: Ethiopia, Pakistan, India	Dec-08	Cornell-IP
		01.3.03 Meeting to identify policy, logistical, or other barriers to minimizing the time from identification of new varieties to the time of their impact in farm fields: Kenya, Iran, Egypt, Turkey	Jun-09	Cornell-IP
	01.4 Develop follow-on phase II proposal with broad input from appropriate experts.	01.4.01 Phase II planning process activated	Jan-09	Cornell-IP
		01.4.02 Workshop of the Durable Rust Resistance in Wheat project and Borlaug Global Rust Initiative meeting	Mar-09	Cornell-IP
		01.4.03 Phase II advanced planning workshop	Mar-09	Cornell-IP
		01.4.04 Phase II proposal complete	Jun-09	Cornell-IP
		01.4.05 Obj 7 scientists to International Wheat Genetics Symposium in Australia	Aug-08	Cornell-IP
		01.4.06 Workshop for scientists working on Objective 5: Breeding (not funded in phase I)	Oct-09	Cornell-IP
		01.4.07 Workshop for scientists working on Objective 9: Exploring Rice Immunity to Rust	Nov-09	Cornell-IP
02 Advocating and Coordinating Global Awareness and Cooperation	02.1 Create Advocacy and Coordination Office with comprehensive web-based knowledge base and portal.	02.1.01 Advocacy and Coordination Office operational	May-08	Cornell-IP
		02.1.02 Web-based wheat rust knowledge base and portal designed	Jun-08	Cornell-IP
		02.1.03 Wheat rust knowledge base and portal operational	Jun-08	Cornell-IP
		02.1.04 Gap analysis of shortfall in funding and research activities completed	Sep-08	Cornell-IP
			Sep-09	Cornell-IP
			Sep-10	Cornell-IP
	02.2 Coordinate Project activities and promote linkages with other partners.	02.2.01 Bi-monthly voice/video conferences between Project Coordinator with Objective Team Leaders begin	Apr-08	Cornell-IP
		02.2.02 Project Coordinator and other Management staff have visited all research sites	Dec-08	Cornell-IP

DRRW: Project Milestones

Objective	Activity	Milestone	target_date	inst and unit
		02.2.03 Awareness of Project 'pushed' to relevant websites and through press releases and other communications	Dec-08	Cornell-IP
			Dec-09	Cornell-IP
			Dec-10	Cornell-IP
		02.2.04 Data collected from participating scientists on project activities that are leveraging additional investments and new partnerships	Sep-08	Cornell-IP
			Sep-09	Cornell-IP
	02.3 Advocate for rational, coordinated, and sustained global strategies through education outreach and through logistical and other support for the Borlaug Global Rust Initiative.	02.3.01 Presentations and other communication tools updated and maintained for advocacy at all levels	Jul-08	Cornell-IP
			Apr-09	Cornell-IP
			Apr-10	Cornell-IP
		02.3.02 Key donor staff are visited by advocacy office personnel or others	Dec-08	Cornell-IP
			Dec-09	Cornell-IP
			Dec-10	Cornell-IP
		02.3.03 High profile advocates (e.g. NE Borlaug, key NARS DGs, etc) visit key actors in donor community	Dec-08	Cornell-IP
			Dec-09	Cornell-IP
			Dec-10	Cornell-IP
		02.3.04 Borlaug Global Rust Initiative global forum for technical and policy discussions.	Mar-09	Cornell-IP
	02.4 Facilitate awareness of the importance of robust policies and strategies for optimized gene deployment.	02.4.01 Gene deployment is accepted as a critical element of the resiliency of wheat production in the developing world.	Dec-08	Cornell-IP
			Dec-09	Cornell-IP
			Dec-10	Cornell-IP
		02.4.02 Scientific societies and policy makers actively address the issue of alternative gene deployment strategies	Dec-08	Cornell-IP
			Dec-09	Cornell-IP
			Dec-10	Cornell-IP
	02.5 Conduct Special Initiatives (ad hoc gatherings, travel facilitation to critical events, etc).	02.5.01 Communication materials developed on how to avoid inadvertently spreading rust spores for international visitors to wheat screening facilities in Kenya and Ethiopia	Apr-08	Cornell-IP
		02.5.02 Plan to prevent spore spread out of Ethiopia established, including purchase of appropriate protective clothing and hotel ☐laundry credit certificates☐ for scientists to wash their contaminated clothes before they return home.	Dec-08	Cornell-IP
		02.5.02 Plan to prevent spore spread out of Kenya established, including purchase of appropriate protective clothing and hotel ☐laundry credit certificates☐ for scientists to wash their contaminated clothes before they return home.	Sep-08	Cornell-IP
		02.5.03 Visits by scientists, from NARS and ARIs to conferences, collaborating laboratories, training courses and screening facilities arranged.	Dec-08	Cornell-IP
			Dec-09	Cornell-IP
			Dec-10	Cornell-IP

DRRW: Project Milestones

Objective	Activity	Milestone	target_date	inst and unit
03 Tracking Wheat Rust Pathogens	03.1 Develop the information platform underpinning a global cereal rust monitoring system	03.1.01a Preliminary standard protocols and methodology for a field survey/sampling system developed (including quickset virulence detection and full scale race analysis/virulence/host data)	Jan-08	U of Sydney-HQ
		03.1.01b Advanced standard protocols and methodology for a field survey/sampling system developed (including quickset virulence detection and full scale race analysis/virulence/host data)	Sep-08	U of Sydney-HQ
		03.1.02a Preliminary standard protocols for data/sample management in National information systems developed	Feb-08	U of Sydney-HQ
		03.1.02b Advanced standard protocols for data/sample management in National information systems developed	Sep-08	U of Sydney-HQ
		03.1.03 Data management platform (database and GIS) for Global monitoring system developed	Oct-08	UN-FAO-HQ
		03.1.04 Baseline datasets (wheat growing areas, varietal distribution, farming systems, crop growth stages & environmental data) developed	Dec-08	ICARDA-HQ
		03.1.05 Wind dispersal models integrated and visualization tools for pathogen status and movements developed	Dec-08	UN-FAO-HQ
	03.2 Develop national capacity to undertake effective pathogen tracking and monitoring	03.2.01 Field survey guidelines and training materials developed; quicksets developed	Feb-08	U of Sydney-HQ
		03.2.02 Baseline Survey Planning Workshop; distribution of survey guidelines and quicksets	Mar-08	ICARDA-HQ
		03.2.03 Training workshops for national information system managers undertaken (in conjunction with international workshops)	Mar-09	ICARDA-HQ
		03.2.04 Baseline Survey Review and Follow-on Planning workshop	Sep-08	Cornell-IP
		03.2.05 National Survey teams established and contributing annually to National and Global Cereal Rust Monitoring Systems in at least 7 countries (Ethiopia and Kenya achieved via Obj 4: Critical Facilities)	Mar-10	ICARDA-HQ
	03.3 Operationalize and implement a Global Cereal Rust Monitoring System	03.3.01 Field data/samples collected via surveys using standard protocols	Jun-08	ICARDA-HQ
			Oct-08	U of Sydney-HQ
			Dec-08	U of Free State-HQ
			Jun-09	ICARDA-HQ
			Oct-09	U of Sydney-HQ
			Dec-09	U of Free State-HQ
			Jun-10	ICARDA-HQ
			Oct-10	U of Sydney-HQ
			Dec-10	U of Free State-HQ
		03.3.02a Preliminary data integration, management and analysis in global monitoring system undertaken	Jul-08	UN-FAO-HQ

DRRW: Project Milestones

Objective	Activity	Milestone	target_date	inst and unit
		03.3.02b Advanced data integration, management and analysis in global monitoring system undertaken	Nov-08	UN-FAO-HQ
			Apr-09	UN-FAO-HQ
			Jul-09	UN-FAO-HQ
			Nov-09	UN-FAO-HQ
			Apr-10	UN-FAO-HQ
			Jul-10	UN-FAO-HQ
			Nov-10	UN-FAO-HQ
		03.3.03a Targeted information products (preliminary) developed and disseminated - via situation bulletins and web applications	Jul-08	UN-FAO-HQ
			Sep-08	UN-FAO-HQ
		03.3.03b Targeted information products (advanced) developed and disseminated - via situation bulletins and web applications	Dec-08	UN-FAO-HQ
			Apr-09	UN-FAO-HQ
			Jul-09	UN-FAO-HQ
			Sep-09	UN-FAO-HQ
			Dec-09	UN-FAO-HQ
			Apr-10	UN-FAO-HQ
			Jul-10	UN-FAO-HQ
			Sep-10	UN-FAO-HQ
			Dec-10	UN-FAO-HQ
	03.4 Pathogen Race and Host Resistance gene distribution	03.4.01 Race analysis (80 survey samples per year) and DNA fingerprint analysis (200 samples per year) conducted at ARIs	Mar-09	U of Sydney-HQ
			Mar-10	U of Sydney-HQ
		03.4.02 Host Resistance gene status of 50-100 varieties determined per year.	Sep-08	U of Sydney-HQ
			Sep-09	U of Sydney-HQ
		03.4.03 Data from pathogen sample analyses and host resistance gene analysis integrated into Global Cereal Rust Monitoring System (ongoing)	Dec-08	UN-FAO-HQ
			Dec-09	UN-FAO-HQ
			Dec-10	UN-FAO-HQ
04 Supporting Critical Rust Screening Facilities in East Africa	04.1 Expand and coordinate the capacity of KARI and EIAR to accurately phenotype wheat genetic resources for reaction to stem rust Ug99 and derivatives.	04.1.01 EIAR and KARI Critical Facility Teams (personnel) operational.	Jun-08	Cornell-IP
		04.1.02 CIMMYT posts Critical Facility Coordinator to Kenya.	Jun-08	CIMMYT-HQ
		04.1.03 Field, laboratory, and greenhouse infrastructure, equipment upgraded/purchased at Njoro Kenya.	Sep-08	KARI-Njoro
		04.1.04 Field and laboratory infrastructure, equipment upgraded/purchased at Debra Zeit, Ethiopia.	Dec-08	EIAR-HQ
		04.1.05 Laboratory and greenhouse infrastructure equipment upgraded/purchased at Ambo, Ethiopia.	Dec-08	EIAR-HQ
		04.1.06 Field and other upgrades; equipment purchases made for Kulumsa	May-09	EIAR-HQ

DRRW: Project Milestones

Objective	Activity	Milestone	target_date	inst and unit
	04.2 Conduct common wheat phenotyping at KARI's Njoro Research Center	04.2.01 Main Season (June-Sept of same year) nursery planned jointly between KARI and CIMMYT-Kenya (CIMMYT acting as International focal point)	Feb-09	KARI-Njoro
				CIMMYT-Kenya
			Feb-10	KARI-Njoro
				CIMMYT-Kenya
			Feb-11	KARI-Njoro
				CIMMYT-Kenya
		04.2.02 Main season (June-Sept of same year) Nursery: seed imported, plots planted and well managed; epiphytotic generated with inoculum of appropriate stem rust race(s)	Sep-08	KARI-Njoro
			Sep-09	KARI-Njoro
			Sep-10	KARI-Njoro
		04.2.03 Main Season (June- Sept of same year) Nursery data collected, compiled; data/seed distributed to originators and where appropriate data to DRRW management	Oct-08	CIMMYT-Kenya
			Oct-09	CIMMYT-Kenya
			Oct-10	CIMMYT-Kenya
		04.2.04 Off Season (Dec of current year through May of next year) nursery planned jointly between KARI and CIMMYT-Kenya (CIMMYT acting as International focal point)	Aug-08	KARI-Njoro
				CIMMYT-Kenya
			Aug-09	KARI-Njoro
				CIMMYT-Kenya
			Aug-10	KARI-Njoro
				CIMMYT-Kenya
		04.2.05 Off season (Dec of previous year-May of same year) Nursery: seed imported, plots planted and well managed; epiphytotic generated with inoculum of appropriate stem rust race(s)	May-08	KARI-Njoro
			May-09	KARI-Njoro
			May-10	KARI-Njoro
		04.2.06 Off season (Dec of previous year-May of same year) Nursery data collected, compiled; data/seed distributed to originators and where appropriate data to DRRW management	Jun-08	CIMMYT-Kenya
			Jun-09	CIMMYT-Kenya
			Jun-10	CIMMYT-Kenya
	04.3 Conduct durum wheat phenotyping at EIAR's Debra Zeit Research Center with inoculum generated at EIAR's Ambo station.	04.3.01 Main Season (June-Nov of same year) nursery planned jointly between EIAR and CIMMYT-Kenya (CIMMYT acting as International focal point)	Feb-09	EIAR-HQ
				CIMMYT-Kenya
			Feb-10	EIAR-HQ
				CIMMYT-Kenya
			Feb-11	EIAR-HQ
				CIMMYT-Kenya
		04.3.02 Main season (June-Nov of same year) Nursery: seed imported, plots planted and well managed; epiphytotic generated with inoculum of appropriate stem rust race(s)	Nov-08	EIAR-HQ

DRRW: Project Milestones

Objective	Activity	Milestone	target_date	inst and unit
			Nov-09	EIAR-HQ
			Nov-10	EIAR-HQ
		04.3.03 Main Season (June- Nov of same year) Nursery data collected, compiled; data/seed distributed to originators and where appropriate data to DRRW management	Dec-08	CIMMYT-Kenya
			Dec-09	CIMMYT-Kenya
			Dec-10	CIMMYT-Kenya
		04.3.04 Off Season (Jan of current year through April of next year) nursery planned jointly between EIAR and CIMMYT-Kenya (CIMMYT acting as International focal point)	Sep-08	EIAR-HQ
			Sep-08	CIMMYT-Kenya
			Sep-09	EIAR-HQ
				CIMMYT-Kenya
			Sep-10	EIAR-HQ
				CIMMYT-Kenya
		04.3.05 Off season (Jan of previous year-April of same year) Nursery: seed imported, plots planted and well managed; epiphytotic generated with inoculum of appropriate stem rust race(s)	Apr-08	EIAR-HQ
			Apr-09	EIAR-HQ
			Apr-10	EIAR-HQ
		04.3.06 Off season (Jan of previous year-April of same year) Nursery data collected, compiled; data/seed distributed to originators and where appropriate data to DRRW management	Jun-08	CIMMYT-Kenya
			May-09	CIMMYT-Kenya
			May-10	CIMMYT-Kenya
	04.4 Provide in service learning opportunities for KARI and EIAR staff	04.4.01 Train EIAR and KARI staff in IWIS	Aug-09	CIMMYT-HQ
		04.4.02 Robert Park completes 6 week sabbatical leave	Dec-08	Cornell-IP
			Dec-09	Cornell-IP
		04.4.03 Visits by/to Z Pretorius in S Africa 2 people EIAR, 2 KARI to SA in Sept 08 and 09, ZP to ET and KE 2x in 08 and 09; EIAR/KARI staff to SA and U of Syd (Feb 09)	Sep-08	Cornell-IP
			Feb-09	Cornell-IP
			Sep-09	Cornell-IP
		04.4.04 International travel by scientists (once per year, 2 Kenya, 3 Ethiopia)	Dec-08	Cornell-IP
			Dec-09	Cornell-IP
			Apr-10	Cornell-IP
		04.4.05 Race analysis for monitoring/management of inoculum; and for seedling analysis of appropriate genetic resources are routine procedures.	Jun-09	KARI-Njoro
		04.4.06 Race analysis for monitoring/management of inoculum; and for seedling analysis of appropriate genetic resources are routine procedures.	Jun-09	EIAR-Ambo

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Objective	Activity	Milestone	target_date	inst and unit
05 Breeding (Conventional and Molecular) to Produce Rust Resistant Wheat Varieties	05.1 Spring bread wheat varieties for irrigated and higher production environments of Africa, Middle East, West, Central and South Asia developed by the Irrigated Spring Bread Wheat Improvement Program, CIMMYT, Mexico.	05.1.01 Field breeding cycle (crop season 10 November-10 May) in Cd. Obregon, Mexico completed. (see detail below)	May-08	CIMMYT-HQ
			May-09	CIMMYT-HQ
			May-10	CIMMYT-HQ
		05.1.02 Seed for International YT and SN of SR resistant vars multiplied at Mexicali (crop season 15 December-10 June). Gene postulation by seedling and MM assays of new lines.	Jun-08	CIMMYT-HQ
			Jun-09	CIMMYT-HQ
			Jun-10	CIMMYT-HQ
		05.1.03 F3 and F4 populations and advanced breeding lines evaluated/selected/harvested at Njoro, Kenya field site (December-April) under stem rust pressure.	Apr-08	CIMMYT-HQ
			Apr-09	CIMMYT-HQ
			Apr-10	CIMMYT-HQ
		05.1.04 Advanced lines planted at Santa Catalina near Quito, Ecuador (crop season Jan-June) for hot-spot testing of yellow rust resistance and data recorded.	Jun-08	CIMMYT-HQ
			Jun-09	CIMMYT-HQ
			Jun-10	CIMMYT-HQ
		05.1.05 End-use quality analysis of about 500 advanced lines that are candidates for international yield trials and screening nurseries.	Sep-08	CIMMYT-HQ
			Sep-09	CIMMYT-HQ
			Sep-10	CIMMYT-HQ
		05.1.06 Field breeding cycle (crop season 15 May-30 October) in Toluca/El Batan, Mexico completed. (see detail below)	Oct-08	CIMMYT-HQ
			Oct-09	CIMMYT-HQ
			Oct-10	CIMMYT-HQ
		05.1.07 Seed of International Yield Trials and Screening Nursery consisting of high yielding SR resistant lines w/ other desirable traits distributed for planting in irrigated and higher production environments .	Oct-08	CIMMYT-HQ
			Oct-09	CIMMYT-HQ
			Oct-10	CIMMYT-HQ
		05.1.08 International Yield Trials grown by NARS partners (November-May), data analyzed and candidate varieties identified for inclusion in 1st year National Variety Registration Trials and simultaneous seed multiplication.	Sep-08	CIMMYT-HQ
			Sep-09	CIMMYT-HQ
			Sep-10	CIMMYT-HQ

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Objective	Activity	Milestone	target_date	inst and unit
	05.2 Spring bread wheat varieties for drought-stressed and low production environments of Africa, Middle East, West, Central and South Asia developed by the Rainfed Spring Wheat Improvement Program, CIMMYT, Mexico.	05.2.01 Field breeding cycle (crop season 10 November-10 May) in Cd. Obregon, Mexico completed. (see detail below)	May-08	CIMMYT-HQ
			May-09	CIMMYT-HQ
			May-10	CIMMYT-HQ
		05.2.02 Seed for International YT and SN of SR resistant vars multiplied at Mexicali (crop season 15 December-10 June). Gene postulation by seedling and MM assays of new lines.	Jun-08	CIMMYT-HQ
			Jun-09	CIMMYT-HQ
			Jun-10	CIMMYT-HQ
		05.2.03 F3 and F4 populations and advanced breeding lines evaluated/selected/harvested at Njoro, Kenya field site (December-April) under stem rust pressure.	Apr-08	CIMMYT-HQ
			Apr-09	CIMMYT-HQ
			Apr-10	CIMMYT-HQ
		05.2.04 Advanced lines planted at Santa Catalina near Quito, Ecuador (crop season Jan-June) for hot-spot testing of yellow rust resistance and data recorded.	Jun-08	CIMMYT-HQ
			Jun-09	CIMMYT-HQ
			Jun-10	CIMMYT-HQ
		05.2.05 End-use quality analysis of about 300 advanced lines that are candidates for international yield trials and screening nurseries.	Sep-08	CIMMYT-HQ
			Sep-09	CIMMYT-HQ
			Sep-10	CIMMYT-HQ
		05.2.06 Field breeding cycle (crop season 15 May-30 October) in Toluca/El Batan, Mexico completed. (see detail below)	Oct-08	CIMMYT-HQ
			Oct-09	CIMMYT-HQ
			Oct-10	CIMMYT-HQ
		05.2.07 Preparation and distribution of International Yield Trials and Screening Nursery consisting of high yielding, drought tolerant lines with stem rust resistance and other desirable traits for planting in target and other countries.	Oct-08	CIMMYT-HQ
			Oct-09	CIMMYT-HQ
			Oct-10	CIMMYT-HQ
		05.2.08 International Yield Trials grown by NARS partners (November-May), data analyzed and candidate varieties identified for inclusion in 1st year National Variety Registration Trials and simultaneous seed multiplication.	Sep-08	CIMMYT-HQ
			Sep-09	CIMMYT-HQ
			Sep-10	CIMMYT-HQ
	05.3 Spring bread wheat varieties for diverse production environments of CWANA region developed by Spring Bread Wheat Improvement Program, ICARDA, Syria.	05.3.01 Field breeding cycle (crop season November-June) in Tel-Hadya (irrigated) completed.	Oct-08	ICARDA-HQ
			Oct-09	ICARDA-HQ
			Oct-10	ICARDA-HQ

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Objective	Activity	Milestone	target_date	inst and unit
		05.3.02 Intermediate segregating generation populations shuttled between Tel-Hadya, Syria and Njoro, Kenya and selection conducted.	Oct-08	ICARDA-HQ
			Oct-09	ICARDA-HQ
			Oct-10	ICARDA-HQ
		05.3.03 Adv. breeding lines (ca.1000) evaluated 2x for stem rust resistance at Njoro, Kenya, leaf rust resistance in Trebol (Lebanon) and yellow rust and grain yield performance at Tel-Hadya. About 400 adv. lines selected and end use-quality determined.	Oct-08	ICARDA-HQ
			Oct-09	ICARDA-HQ
			Oct-10	ICARDA-HQ
		05.3.04 Second year yield evaluations conducted for about 400 advanced lines at Tel-Hayda, and Breda, Syria; and seed multiplied for regional distribution.	Jun-08	ICARDA-HQ
			Jun-09	ICARDA-HQ
			Jun-10	ICARDA-HQ
		05.3.05 Yield Trials and Screening Nurseries for CWANA region consisting of high yielding, drought tolerant lines (about 40% resistant to stem rust) with other desirable traits prepared and distributed.	Oct-08	ICARDA-HQ
			Oct-09	ICARDA-HQ
			Oct-10	ICARDA-HQ
		05.3.06 YT grown by NARS (November-June), analysis of multi-site grain yield and other data, and candidate replacement varieties identified for inclusion in 1st year National Variety Registration Trials and simultaneous seed multiplication.	Oct-08	ICARDA-HQ
			Oct-09	ICARDA-HQ
			Oct-10	ICARDA-HQ
	05.4 Developing and delivering stem rust resistant facultative and winter bread wheat varieties for CWANA region.	05.4.01 Crossing block grown in the field at Tel-Hadya, Syria during October-June crop season and about 130 simple crosses made.	Jun-08	ICARDA-HQ
			Jun-09	ICARDA-HQ
		05.4.02 Crossing block and F1 grown in the field at Tel-Hadya, Syria during October-June crop season and about 100 BC1 (backcross 1) made.	Jun-09	ICARDA-HQ
			Jun-10	ICARDA-HQ
		05.4.03 Crossing block and BC1 grown in the field at Tel-Hadya, Syria during October-June crop season, markers applied and about 100 BC2 (2nd backcross) made on selected plants.	Jun-10	ICARDA-HQ
	05.5 Developing and delivering stem rust resistant photosensitive spring bread wheat varieties for Central Asia.	05.5.01 Approx. 60 crosses made at Cd. Obregon fields (crop season Nov.-April) between sources carrying race-specific stem rust resistance/durable resistance and varieties, new breeding lines and other wheat materials that have adaptation in Central Asia.	Apr-08	CIMMYT-KZ
		05.5.02 Crossing block and simple crosses grown at Toluca fields (crop season May-October) at and about 60 top or three-way crosses made.	Oct-08	CIMMYT-KZ

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Objective	Activity	Milestone	target_date	inst and unit
		05.5.03 F1Top and BC1 grown at Cd. Obregon fields, markers applied (where available) for desired haplotypes; or plants with better characteristics selected.	Apr-09	CIMMYT-KZ
		05.5.04 F2 populations grown at Toluca fields and plant of desired agronomic characteristics and yellow rust resistance selected.	Oct-09	CIMMYT-KZ
		05.5.05 F3 pops grown at Cd. Obregon fields, markers applied and plants of desired haplotype retained. For crosses involving resistance genes without markers, pops grown in both Kenya and Mexico; selection of pops in Obregon based on Kenya SR data.	Apr-10	CIMMYT-KZ
		05.5.06 F4 populations grown at El Batan fields in Mexico, best lines selected, harvested for shipment to Northern Kazakhstan and Kenya.	Nov-10	CIMMYT-KZ
	05.6 Developing and delivering stem rust resistant spring, facultative and winter bread wheat varieties for China.	05.6.01 Crossing block grown in China fields and 100 simple crosses involving leading varieties/promising advanced lines x sources of resistance.	Jun-08	CIMMYT-Bejing
		05.6.02 Crossing block and F1 grown in greenhouse/fields in China, molecular markers applied and BC1 and BC2 made.	Sep-09	CIMMYT-Bejing
		05.6.03 BC2 and BC2F2 grown in field/greenhouse, molecular markers applied resistant plants selected.	Sep-10	CIMMYT-Bejing
	05.7 Durum Wheat varieties for Africa, Middle East, Asia and Latin America by Durum Wheat Improvement Program, CIMMYT, Mexico.	05.7.01 Crossing block grown in Cd. Obregon fields (crop season November-April) and about 150 simple crosses made between elite durum wheat lines from CIMMYT and sources of stem rust resistance.	May-08	CIMMYT-HQ
			May-09	CIMMYT-HQ
			May-10	CIMMYT-HQ
		05.7.02 Existing advanced breeding lines evaluated in Debre Zeit, Ethiopia (crop season Jan-April) for stem rust resistance. Lines found resistant to stem rust used in breeding program and distributed to NARS.	Oct-08	CIMMYT-HQ
			Oct-09	CIMMYT-HQ
			Oct-10	CIMMYT-HQ
		05.7.03 Crossing block and F1 grown at Toluca/El Batan, Mexico fields (crop season 15 May-30 October), and about 100 backcrosses/top crosses made. 150 new simple crosses also made.	Oct-08	CIMMYT-HQ
			Oct-09	CIMMYT-HQ
			Oct-10	CIMMYT-HQ
		05.7.04 BC1/Top crosses grown in Cd. Obregon fields, molecular markers applied if available, best plants selected and harvested as bulks. New BC1/Top crosses made on new simple crosses.	May-09	CIMMYT-HQ
			May-10	CIMMYT-HQ
		05.7.05 F2 and BC1/Top crosses grown at Toluca/El Batan fields, selected for resistance to diseases and agronomic types and molecular markers applied where available. Selected plants harvested individually in F2 and as bulks in BC1/Top.	Oct-09	CIMMYT-HQ

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Objective	Activity	Milestone	target_date	inst and unit
			Oct-10	CIMMYT-HQ
		05.7.06 F2 pops grown in Obregon; best plants selected phenotypically and w/ markers. F3 lines grown in Obregon and Debre Zeit (Jan-Apr); F3 plants selected in Obregon based on DZ SR and grain data. Best lines transferred to Eth. breeding program.	May-10	CIMMYT-HQ
		05.7.07 F4 lines grown in Toluca/El Batan fields, selected for resistance to diseases and agronomic characteristics and harvested. Selected F4 plots harvested for F4-derived-F5 bulks after taking 5 single spikes for purification.	Oct-10	CIMMYT-HQ
	05.8 Durum Wheat varieties for CWANA by Durum Wheat Improvement Program, ICARDA, Syria.	05.8.01 Crossing block and F1 grown at Tel-Hadya, Syria fields (November-June) and about 300 Simple and 200 three-ways crosses made.	Jun-08	ICARDA-HQ
			Jun-09	ICARDA-HQ
			Jun-10	ICARDA-HQ
		05.8.02 Existing advanced lines and segregating populations from crosses involving stem rust resistant parents in the breeding program screened at Debre Zeit, Ethiopia.	Oct-08	ICARDA-HQ
			Oct-09	ICARDA-HQ
			Oct-10	ICARDA-HQ
		05.8.03 F2 (simple) and F1 (3-ways) grown at Terbol (Lebanon) fields and plants selected for agronomic features and disease resistance and harvested as bulk.	Oct-08	ICARDA-HQ
			Oct-09	ICARDA-HQ
			Oct-10	ICARDA-HQ
		05.8.04 F3 (simple) and F2 (3-ways) grown; pedigree selection applied at Tel Hadya in populations showing good agronomic features at Tel Hadya, Breda, and Terbol.	Jun-09	ICARDA-HQ
			Jun-10	ICARDA-HQ
		05.8.05 F4 (simple) and F3 (3-ways) from individual plants grown at Debre Zeit and Terbol fields; lines showing resistance to stem rust in Debre Zeit and good agronomic features retained in Terbol.	Oct-09	ICARDA-HQ
			Oct-10	ICARDA-HQ
		05.8.06 F5 (simple) and F4 (3-ways) space-grown at Tel-Hadya fields; individual plants selected for agronomic characteristics and disease resistance, harvested and those with good grain retained.	Jun-10	ICARDA-HQ
		05.8.07 F6 (simple) and F5 (3-ways) grown at Terbol and Debre Zeit; lines resistant to stem rust in Debre Zeit harvested at Terbol for CWANA and at Debre Zeit for Ethiopia.	Oct-10	ICARDA-HQ
06 Developing and Optimizing Markers for Rust Resistance	06.1 Optimization of markers for previously characterized rust resistance gene markers	06.1.01 Compile & prioritize a comprehensive list of major genes, their markers, and genome locations	Jun-08	U of MN-PB
		06.1.02 Optimize high priority markers for major known genes in first 18 months	Sep-09	U of MN-PB

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Objective	Activity	Milestone	target_date	inst and unit
		06.1.03 Optimize high priority markers for newly discovered major known genes in year 3	Dec-10	U of MN-PB
	06.2 Haplotyping uncharacterized rust resistant genotypes to infer novelty and to plan new mapping experiments	06.2.01 Acquire seed of genetic stocks, germplasm and varieties for haplotyping	Mar-08	Cornell-PBG
		06.2.02 Haplotype known sources of rust resistance and susceptible controls at known loci	Feb-09	Cornell-PBG
		06.2.03 Haplotype novel sources of rust resistance that are uncharacterized at major resistance gene loci	May-10	Cornell-PBG
		06.2.04 Assess stem rust resistance gene marker diversity	Dec-10	Cornell-PBG
	06.3 Pyramiding novel sources of rust resistance	06.3.01 Make first round of crosses among high priority known sources of major genes for pyramiding in an adapted background	Jun-08	Cornell-PBG
		06.3.02 Select plants that are homozygous for two genes, bulk harvest and deliver to breeding programs	Mar-09	Cornell-PBG
		06.3.03 Make second round of crosses among high priority known sources of effective major genes for pyramiding in an adapted background.	Dec-09	Cornell-PBG
		06.3.04 Select plants that are homozygous for three genes, bulk harvest and deliver to breeding programs.	Dec-10	Cornell-PBG
	06.4 Mapping novel sources of rust resistance	06.4.01 Identify new sources of rust resistance and develop mapping populations	Jun-08	CIMMYT-HQ
			Jun-08	UC Davis-HQ
		06.4.02 Select APR mapping populations based on phenotype	May-09	CIMMYT-HQ
		06.4.03 Genotype 4-6 selected APR mapping populations	Jan-10	CIMMYT-HQ
		06.4.04 Analyze rust resistance QTL data for APR, complete the mapping of novel sources of rust resistance	Dec-10	CIMMYT-HQ
				CSIRO-HQ
				UC Davis-HQ
07 Reducing Linkage Drag Associated with Rust Resistance Genes	07.1 Separate Sr37, Sr39, Sr43, and Sr2BS from linkage drag and combine two resistance genes onto a single linkage block	07.1.01 Molecular cytogenetic characterization of four original translocations lines carrying Sr37, Sr39, Sr43, and Sr2BS using SSR markers and FGISH	Jun-08	USDA-ND
		07.1.02 Production of F1 hybrids between the original translocations lines with Ph1 mutant (ph1b) and Ph1-deficienct aneuploids	Jul-08	USDA-ND
		07.1.03 Production of the BC1F1 and F2 populations from crosses of the original translocations lines with Ph1 mutant (ph1b) and Ph1-deficienct aneuploids	Dec-08	USDA-ND
		07.1.04 Production of F1 hybrid plants of the selected BC1F1 plants crossed with Chinese Spring or elite Sr susceptible lines	May-09	USDA-ND
		07.1.05 Molecular and cytological identification of shorter translocations for Sr37 from the F2 and BC1F1-derived populations	Nov-09	USDA-ND

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Objective	Activity	Milestone	target_date	inst and unit
		07.1.06 Molecular and cytological identification of shorter translocations for Sr39 from the F2 and BC1F1-derived populations	Apr-10	USDA-ND
		07.1.07 Molecular and cytological identification of shorter translocations for Sr43 from the F2 and BC1F1-derived populations	Aug-10	USDA-ND
		07.1.08 Molecular and cytological identification of shorter translocations for Sr2BS from the F2 and BC1F1-derived populations	Dec-10	USDA-ND
	07.2 Separate Sr32, Sr40, Sr44, Sr6V, and Sr5S from linkage drag	07.2.01 Molecular cytogenetic characterization of two original translocations lines carrying Sr32 and Sr40 using SSR markers and FGISH	Mar-08	USDA-KS
		07.2.02 Production of F1 hybrids between two translocations lines carrying Sr32 and Sr40 with Ph1 mutant (ph1b)	Jun-08	USDA-KS
		07.2.03 Production of the BC1F1 and F2 populations from crosses of two translocations lines carrying Sr32 and Sr40 with Ph1 mutant (ph1b)	Dec-08	USDA-KS
		07.2.04 Identification of compensating translocations for Sr44, Sr5S, and Sr6V from the existing F2 populations.	Feb-09	USDA-KS
		07.2.05 Production of F1 hybrid plants of the selected BC1F1 plants carrying Sr32 and Sr40 crossed with Chinese Spring or elite Sr susceptible lines	May-09	USDA-KS
		07.2.06 Production of F1 hybrids between three translocations lines carrying Sr44, Sr5S, and Sr6V with Ph1 mutant (ph1b)	Jun-09	USDA-KS
		07.2.07 Molecular and cytological identification of shorter translocations for Sr32 from the F2 and BC1F1-derived populations	Nov-09	USDA-KS
		07.2.08 Production of the BC1F1and F2 populations from crosses of the translocations lines carrying Sr44, Sr5S, and Sr6V with Ph1 mutant (ph1b)	Dec-09	USDA-KS
		07.2.09 Molecular and cytological identification of shorter translocations for Sr40 from the F2 and BC1F1-derived populations	Apr-10	USDA-KS
		07.2.10 Production of F1 hybrid plants of the selected BC1F1 plants carrying Sr44, Sr5S, and Sr6V crossed with Chinese Spring or elite Sr susceptible lines	May-10	USDA-KS
		07.2.11 Molecular and cytological identification of shorter translocations for Sr44 from the F2 and BC1F1-derived populations	Nov-10	USDA-KS
		07.2.12 Production of F1 hybrids by crossing the short translocation lines carrying Sr32 and Sr40 with adapted wheat cultivars	Dec-10	USDA-KS
	07.3 Evaluate parental lines, segregation populations, and new translocation lines for reactions to stem rust	07.3.01 Evaluation of all original translocations lines for reactions to the locally maintained stem rust races.	Oct-08	USDA-MN
		07.3.02 Identification of the stem rust races other than Ug99 used for detecting each of alien genes Sr32, Sr37, Sr39, Sr40, Sr43, Sr44, Sr2BS, Sr5S, and Sr6V.	Nov-08	USDA-MN

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Objective	Activity	Milestone	target_date	inst and unit
		07.3.03 Selection of BC1F1 plants carrying Sr32, Sr37, Sr39, Sr40, Sr43, and Sr2S by stem rust evaluation.	Mar-09	USDA-MN
		07.3.04 Selection of resistant plants carrying Sr32 and Sr37 by stem rust evaluation of the F2 and BC1F1-derived populations.	Sep-09	USDA-MN
		07.3.05 Selection of resistant plants carrying Sr39 and Sr40 by stem rust evaluation of the F2 and BC1F1-derived populations.	Feb-10	USDA-MN
		07.3.06 Selection of BC1F1 plants carrying Sr44, Sr5S, and Sr6V by stem rust evaluation.	Mar-10	USDA-MN
		07.3.07 Selection of resistant plants carrying Sr43 and Sr44 by stem rust evaluation of the F2 and BC1F1-derived populations.	Jul-10	USDA-MN
		07.3.08 Selection of resistant plants carrying Sr2BS, Sr5BS and Sr6V by stem rust evaluation of the F2 and BC1F1-derived populations.	Sep-10	USDA-MN
		07.3.09 Evaluation of new translocation lines carrying each of the alien genes Sr32, Sr37, Sr39, Sr40, Sr43, and Sr44 for resistance to Ug99.	Dec-10	USDA-MN
08 Discovering New Sources of Rust Resistance in Wild Wheat and Wild Barley	08.1 Screening wild relatives of wheat and durum at the seedling stage with race Ug99	08.1.01 Accessions of wild relatives of wheat and durum are collected and processed for planting.	Jan-08	USDA-MN
			Jan-09	USDA-MN
			Jan-10	USDA-MN
		08.1.02 Growing seedling for testing against race Ug99.	Mar-08	USDA-MN
			Mar-09	USDA-MN
			Mar-10	USDA-MN
		08.1.03 Reactions to race Ug99 are known.	May-08	USDA-MN
			May-09	USDA-MN
			May-10	USDA-MN
		08.1.04 Growing seedling for testing against races TPMK and TTTT.	Jul-08	USDA-MN
			Jul-09	USDA-MN
			Jul-10	USDA-MN
		08.1.05 Reactions to races TPMK and TTTT are known.	Sep-08	USDA-MN
			Sep-09	USDA-MN
			Sep-10	USDA-MN
		08.1.06 Selected accessions/plants within an accession are grown in isolation to produce seed for progeny testing.	Dec-08	USDA-MN
			Dec-09	USDA-MN
			Dec-10	USDA-MN
	08.2 Screening wild relatives of barley at the seedling stage with Ug99	08.2.01 Accessions of wild relatives of barley are collected and processed for planting.	Jan-08	U of MN-PP
			Jan-09	U of MN-PP
			Jan-10	U of MN-PP
		08.2.02 Growing seedling for testing against race Ug99.	Mar-08	U of MN-PP
			Mar-09	U of MN-PP

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Objective	Activity	Milestone	target_date	inst and unit
			Mar-10	U of MN-PP
		08.2.03 Reactions to race Ug99 are known.	May-08	U of MN-PP
			May-09	U of MN-PP
			May-10	U of MN-PP
		08.2.04 Growing seedling for testing against races MCCF and QCCJ.	Jul-08	U of MN-PP
			Jul-09	U of MN-PP
			Jul-10	U of MN-PP
		08.2.05 Reactions to races MCCF and QCCJ are known.	Sep-08	U of MN-PP
			Sep-09	U of MN-PP
			Sep-10	U of MN-PP
		08.2.06 Selected accessions/plants within an accession are grown in isolation to produce seed for progeny testing.	Dec-08	U of MN-PP
			Dec-09	U of MN-PP
			Dec-10	U of MN-PP
	08.3 Screening under field conditions for adult plant resistance of ICARDA collection of wild tetraploids at Debre Zeit, Ethiopia	08.3.01 Multiplication of ICARDA's collection of wild tetraploid relatives of wheat at ICARDA	Jul-08	ICARDA-HQ
		08.3.02 Field screening and selection of wild tetraploids for APR to Ug99 at Debre Zeit, Ethiopia; using techniques which preclude escapes	Aug-09	EIAR-HQ
		08.3.03 Field screening and selection of accessions/selections showing APR in year 1; at Debre Zeit, Ethiopia; using techniques which preclude escapes; dissemination of results through project website	Aug-10	EIAR-HQ
	08.4 Introgressing resistance from T. timopheevii and Ae. speltoides to wheat	08.4.01 15-20 Accessions of T. timopheevii and Ae. speltoides are planted and Sr phenotype confirmed	Jan-08	USDA-KS
			Oct-08	USDA-KS
			Nov-09	USDA-KS
		08.4.02 F1 hybrids produced between 5-8 Ae. speltoides and 8 T. timopheevii accessions and cultivated wheat	May-08	USDA-KS
			Mar-09	USDA-KS
			Mar-10	USDA-KS
		08.4.03 BC1F1 seeds produced for ~15 wild accession crosses	Sep-08	USDA-KS
			Jul-09	USDA-KS
			Jul-10	USDA-KS
		08.4.04 BC1F1 progeny planted and stem rust resistant progeny identified	Nov-08	USDA-KS
			Oct-09	USDA-KS
			Aug-10	USDA-KS
		08.4.05 BC2F1 seeds produced	Feb-09	USDA-KS
			Jan-10	USDA-KS
		08.4.06 BC2F1 progeny planted and stem rust resistant progeny identified	Apr-09	USDA-KS
			Apr-10	USDA-KS
			Dec-10	USDA-KS
		08.4.07 Sr screening data on BC2F2 plants	Dec-09	USDA-MN

DRRW: Project Milestones

Objective	Activity	Milestone	target_date	inst and unit
	08.5 Introgressing resistance from Ae. sharonensis to wheat	08.5.01 Hybrids Ae. sharonensis x ph mutant obtained	Jan-08	U of MN-PP
			Nov-08	U of MN-PP
			Nov-09	U of MN-PP
		08.5.02 Hybrids between previous and ant-gametocidal mutant obtained	Jun-08	U of MN-PP
			May-09	U of MN-PP
			Mar-10	U of MN-PP
		08.5.03 First generation hybrids with a spring wheat cultivar obtained	Oct-08	U of MN-PP
			Jul-10	U of MN-PP
		08.5.04 Resistant fifth backcross progenies obtained	Mar-09	U of MN-PP
			Aug-10	U of MN-PP
		08.5.05 Homozygous resistant BC5 selected	Apr-09	U of MN-PP
			Oct-10	U of MN-PP
		08.5.06 Mapping F2 population of RxS Ae. sharonensis obtained	Jun-09	U of MN-PP
			Nov-10	U of MN-PP
		08.5.07 Genetics and mapping Resistance completed	Dec-10	U of MN-PP
	08.6 Introgressing resistance from wild barley and landraces to barley	08.6.01 Hybrids between wild barley/landraces and barley made	Jan-08	U of MN-PP
			Jan-09	U of MN-PP
			Feb-10	U of MN-PP
		08.6.02 F2 generation phenotyped and DNA extracted	Apr-08	U of MN-PP
			Apr-09	U of MN-PP
			May-10	U of MN-PP
		08.6.03 F3 evaluations made for resistance and DArT genotyping (NOTE: NOT funded by this grant)	Jun-08	U of MN-PP
			Jun-09	U of MN-PP
			Jul-10	U of MN-PP
		08.6.04 Genes for Ug99 resistance mapped and markers identified (NOTE: not funded by this Grant)	Sep-08	U of MN-PP
			Sep-09	U of MN-PP
			Oct-10	U of MN-PP
		08.6.05 Progeny with Ug99 resistance selected from backcross populations	Oct-08	U of MN-PP
			Oct-09	U of MN-PP
			Nov-10	U of MN-PP
		08.6.06 Distribution of agronomically advanced BC progeny distributed to breeders	Nov-08	U of MN-PP
			Nov-09	U of MN-PP
			Dec-10	U of MN-PP
09 Exploring Rice Immunity to Rust	09.1 Establish a panel of stem rust isolates (propagate, maintain and increase cultures) for screening rice mutants	09.1.01 A panel of 30 isolates of Puccinia f. sp. multiplied and ready for screening	Jul-08	USDA-MN
	09.2 High throughput preliminary screening of rice mutants and rice collections (cultivated, landrace, and wild accessions) with a bulk of rust isolates	09.2.01 HTP protocols and conditions for screening rice plants established	Dec-08	U of MN-PP

DRRW: Project Milestones

Objective	Activity	Milestone	target_date	inst and unit
		09.2.02 5,000 rice lines (500 pools of 10-20 bulked lines) screened for rust reaction	Dec-09	U of MN-PP
		09.2.03 A total of 10,000 rice lines screened for rust reaction	Dec-10	U of MN-PP
	09.3 Develop a HTP microscopic analysis technique for altered response to rust infection in relevant rice mutant populations	09.3.01 Establish microscopic and macroscopic HTP protocol and screen IR64 mutant lines for rust infection.	Dec-08	CSIRO-HQ
		09.3.02 Pre-selected mutant lines screened by microscopy, cytological analysis of blast-susceptible IR64 mutant lines completed.	Dec-09	CSIRO-HQ
		09.3.03 Rust penetration phenotypes on segregating progeny and pyramided rust susceptible mutant lines determined.	Nov-10	CSIRO-HQ
	09.4 HTP screening for loss-of-resistance to rice pathogens	09.4.01 20 rice mutants with loss of blast resistance identified	Jul-08	IRRI-HQ
		09.4.02 40 rice mutants with loss of blast resistance identified; a series of double mutant (about 5) established	Jun-09	IRRI-HQ
		09.4.03 60 rice mutants with loss of blast resistance identified, and provided for evaluation with rust	Jun-10	IRRI-HQ
	09.5 Detailed phenotypic evaluation of selected mutants with multiple rust fungi and races including Ug99	09.5.01 Rust response phenotypes of 10 pre-selected rice mutants determined	Dec-08	U of MN-PP
		09.5.02 Rust response phenotypes of 20 rice mutants determined	Oct-09	U of MN-PP
		09.5.03 Rust response phenotypes of 50 rice mutants determined; with about 5 mutants manifesting rust-susceptible phenotypes	Nov-10	U of MN-PP
	09.6 Genetically characterize populations of rice that segregate for stem rust reaction	09.6.01 Inheritance of rust response phenotype determined in 5 mutants	Oct-09	IRRI-HQ
		09.6.02 Allelic relationships of 5 loci determined, and establishment of series of double mutants of multiple rust response.	Nov-10	IRRI-HQ
	09.7 Determine the spectrum of altered response to multiple pathogens (panel of rust fungi and rice pathogens)	09.7.01 At least 5 rice mutants with heritable rust response phenotypes characterized for physiological and biochemical response to rust and rice pathogens	Nov-10	IRRI-HQ
	09.8 Chip-based mapping and positional cloning	09.8.01 Locations of genetic lesions for 5 disease-susceptible mutants determined by chip-hybridization	Dec-08	IRRI-HQ
		09.8.02 Determination of loci in 10 susceptible mutants; at least 5 double mutants produced and evaluated	Jun-10	IRRI-HQ
	09.9 Isolate T-DNA tagged rust-susceptible mutants and gene identification by co-segregation analysis	09.9.01 A panel of 15 isolates of stripe and stem rust fungi multiplied and ready for screening in China	Oct-08	IRRI-HQ
		09.9.02 Screening of 5,000 insertions lines completed	Dec-09	IRRI-HQ
		09.9.03 Complete screening of total of 10,000 lines; at least 3 T-DNA rice mutants identified that show susceptibility to rust, and insertion sites identified	Nov-10	IRRI-HQ
10 Project Management	10.1 Establish project management unit	10.1.01 Staff hired	May-08	Cornell-IP
		10.1.02 Programmatic and financial management systems established	Jun-08	Cornell-IP
	10.2 Implement subcontracts and assess implementation at periodic intervals	10.2.01 International subcontracts negotiated	May-08	Cornell-IP

DRRW: Project Milestones

Objective	Activity	Milestone	target_date	inst and unit
		10.2.02 Quarterly invoice period ends	Sep-08	Cornell-IP
			Dec-08	Cornell-IP
			Mar-09	Cornell-IP
			Jun-09	Cornell-IP
			Sep-09	Cornell-IP
			Dec-09	Cornell-IP
			Mar-10	Cornell-IP
			Jun-10	Cornell-IP
			Sep-10	Cornell-IP
			Dec-10	Cornell-IP
		10.2.03 Global Access Strategy agreed	Mar-09	Cornell-IP
	10.3 Programmatic development	10.3.01 External Project Advisory Committee identified	Jun-08	Cornell-IP
		10.3.02 Objective team leaders convened in Australia	Aug-08	Cornell-IP
		10.3.03 Advocacy plan developed and implementation initiated (in support of Objective 2)	Sep-08	Cornell-IP
		10.3.04 Planning and development of second-phase proposal completed (in support of Objective 1)	Jun-09	Cornell-IP
	10.4 Project management	10.4.01 Management component of project website developed (to enable programmatic management by Obj/Task leaders)	Jun-08	Cornell-IP
		10.4.02 Annual report prepared and submitted (period February - September 2008)	Jan-09	Cornell-IP
		10.4.03 Annual report prepared and submitted (period October 2008 - September 2009)	Jan-10	Cornell-IP
		10.4.04 Annual meeting planned and completed ('09 also in Obj 1)	Mar-09	Cornell-IP
			Dec-10	Cornell-IP
	10.5 Special initiatives	10.5.01 Gender strategy developed by consultant outlining opportunities across the project for the engagement of women is agreed by Cornell and BMGF program officer	Sep-08	Cornell-IP
		10.5.02 Roadmap in place for strengthening Ethiopia's wheat improvement and seed sector for rapid upgrade of Ethiopian wheat to varieties with multi-genic resistance	Jan-09	Cornell-IP