Chapter I

Rapid Deployment of Rust-resistant Wheat Varieties: ICARDA's Experience and Lessons Learned

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1.1 Background

The emergence of Ug99 in Uganda (1999) and its variants elsewhere, its quick spread to neighboring countries in East Africa and the Middle East and anticipated potential spread further to South Asia and East Asia caused great alarm amongst the international community. About 85% of widely grown commercial wheat varieties from 18 African and Asian countries were found susceptible to Ug99. An estimated 52% of total wheat area of 74.6 million hectares planted with wheat in these countries which collectively represent 40% of global wheat production is planted with susceptible varieties. Ug99 (including its virulent races) considered a serious threat to global wheat production with potentially catastrophic consequences which could trigger a global food crisis. In the meantime the spread of strains of yellow rust virulent on varieties carrying the Yr27 gene in west and central Asia has exacerbated the anticipated food crisis in times of increasing cereal prices and market uncertainties (Shiferaw et al 2013).

In response to Ug99 crisis, CIMMYT and ICARDA in partnership with a number of National Agricultural Research Systems (NARS) have initiated the Borlaug Global Rust Initiative (ex GRI) under the leadership of the late Nobel Prize laureate Dr Norman Borlaug. Development and deployment of resistant varieties, adequate surveillance systems and

effective plant protection strategies are important elements of an integrated wheat rust control strategy to replace widely grown susceptible varieties and ensure national, regional and global food security (Osborn and Bishaw 2009). Under the BGRI, CIMMYT, ICARDA and a number of NARS from developed and developing countries have tested thousands of accessions in Kenya and Ethiopia. A number of elite lines with adequate resistance against Ug99 and with up to 15% yield increase have been identified through such collaborative effort. Some of these materials were distributed as part of Elite Bread Wheat Yield Trials (EBWYT) and Stem Rust Resistance Screening Nurseries (SRRSN) by CIMMYT and ICARDA.

The most pressing challenge is not only developing rust resistance varieties, but finding innovative and flexible approaches to fast-track variety release and accelerate seed multiplication to ensure quick delivery to farmers for wider scale adoption and diffusion of these varieties both at national and regional levels. Availability of and access to wheat seed of resistant varieties is key to counter the threat of rusts and ensure food security. Osborn and Bishaw (2009) highlighted the key elements for ensuring rapid dissemination of wheat rust resistant varieties to farmers.

ICARDA in collaboration with CIMMYT and/or NARS has developed a number of multi-lateral and bilateral projects to counter the threat of stem rust and yellow rust. This paper summarizes ICARDA's experiences and lessons learned in implementing these projects.

1.2 Wheat projects and target countries

The first, CIMMYT-ICARDA joint project entitled 'Accelerated Seed Multiplication to Counter the Threat of Stem Rust in Wheat' covered six countries along the path of Ug99 in Africa and Asia: Afghanistan, Bangladesh, Egypt, Ethiopia, Nepal and Pakistan. ICARDA implemented the project in Egypt, Ethiopia and Pakistan whereas CIMMYT was responsible for Afghanistan, Bangladesh and Nepal. The second CIMMYT-ICARDA project was the 'Wheat Productivity Enhancement Program' in Pakistan and supported by USDA focusing on Ug99. The third was an ICARDA-EIAR bilateral project 'Rapid Deployment of High Yielding and Rust-resistant Wheat Varieties for Achieving Food

Security in Ethiopia' prompted by yellow rust epidemics in 2010 and supported by USAID.

The primary objectives of these projects were to ensure fast replacement of existing commercial varieties that are vulnerable to new races of stem rust and yellow rust by minimizing the time lag from the identification of potential resistant varieties to their availability in farmers' fields working with national stakeholders across the wheat value chain including policy makers, NARS, national seed programs, development practitioners and farmers.

The project target countries were selected for various reasons. First, wheat contributes substantially to daily caloric intake (up to 30%) and some countries have the highest per capita wheat consumption in the world (180-200 kg). Second, wheat occupies the highest percentage of cereal area and production (up to 80%) and is also the main staple crop of the country. Third, wheat area is extensively planted with Ug99 susceptible varieties and hence higher potential vulnerability to rust epidemics. Fourth, there is endemic domestic food insecurity where millions of tons are imported as food aid which could be exacerbated due to Ug99 epidemics. Fifth, the strength of the national seed sector is highly variable among the targeted countries operating under a wide range of policy, regulatory and institutional frameworks and technical constraints underpinned by poor socio-economic conditions of farmers. Such inherent weaknesses in the national seed industries hinder farmers' rapid access to new resistant wheat varieties in nearly all countries at risk of wheat rust.

1.3 Framework and Approaches

Development and deployment of resistant varieties is one of the key tools for wheat rust management. These could only be achieved by having effective contingency planning for organized fast-track release of new varieties and accelerated seed multiplication under pinned by flexible policies, and commitments by national and/or international community of stakeholders (Osborn and Bishaw, 2009).

A framework for fast track variety testing and release and accelerated seed multiplication was undertaken to address the objectives of the different projects as follows (see Figure 1.1):

- Identifying stem rust (Ug99) and yellow rust resistant wheat elite lines combined with better agronomic performance;
- Fast track testing and release of new rust-resistant wheat varieties through national dialogue with stakeholders;
- Popularizing and demonstrating newly released rust resistance wheat varieties in collaboration and partnership with extension services and development practitioners;
- Accelerating seed multiplication of promising lines (pre-release) or released varieties (post-release) to produce sufficient amount of early generation seed (breeder, pre-basic and basic seed);
- Accelerating large-scale certified seed production of released varieties by partnering with existing public and/or private seed sector;
- Distributing small seed-packs of released varieties to initiate on-farm seed production mobilizing farmers and assisting in informal varietal diffusion;
- Strengthening the infrastructure and human resources capacity of key stakeholders including farmers; and
- Monitoring and evaluation of project deliverables including adoption and impact studies

1.3.1 Screening rust resistance wheat

In order to safe-guard against the release of Ug99 susceptible varieties, the international collaboration was maintained where new elite germplasm from national and international breeding programs, potentially promising lines under national performance trials or newly released commercial varieties were continuously tested and monitored for resistance to Ug99 and its variants in hot spots in Kenya and Ethiopia. In addition, to Ug99, promising lines were also tested against yellow rust in Ethiopia and Syria.

The wheat research strategy against the threat of stem rust race Ug99 and other rusts anchored on the following activities:

- Screening national germplasm (old varieties, commercial varieties, promising lines, breeding materials) for resistance against Ug99 in hot spots;
- Identifying resistance genes that are effective against Ug99 and local races of stem rust, yellow rust and leaf rust that carries durable resistance using molecular tools; and
- Incorporating diverse resistance genes into adapted cultivars and evaluate them in hot spots to develop new high yielding varieties.

From the outset, several accessions have been screened in Kenya and shared globally with NARS through CIMMYT and ICARDA as part of EBWYT and SRRSN since 2005.

1.3.2 Fast-track variety testing and release

Variety release encompasses a broadly interrelated series of activities, from identifying promising lines for further testing to releasing a new variety and making available breeder seed for further multiplication (Bishaw and van Gastel 2010). NARS follow conventional plant breeding protocols using both performance (VCU = Value for Cultivation and Use) and registration (DUS = Distinctness, Uniformity and Stability) trials for official release of new varieties (for details see Turner and Bishaw, 2016). Egypt and Pakistan have partially independent compulsory variety testing and release system requiring both registration and performance trials. In Egypt, ARC conducts the VCU trials and the Central Administration for Seed Testing and Certification the DUS trials while the release is approved by the NVRC. In Pakistan, the National Wheat Coordinated Program affiliated with NARC and under the Pakistan Agricultural Research Council performs the VCU testing and FSCRD the DUS testing whereas the release is approved by the Provincial Seed Council. In Ethiopia, the release system is purely dependent on performance testing conducted by the NARS, evaluated by the technical committee and approved by a NVRC under the Animal and Plant Health Regulatory Directorate. In almost all three cases the recommendations comes from the technical committees established for the purpose and providing advice to the NVRC.

Although NARS are dependent on common germplasm pool introduced from IARCs, it is not always clear how many years of testing would be required before these lines are finally enter variety release trials based on

their performance. The serious threat of wheat rust means that variety evaluation and release may need to be streamlined so that it is efficient and effective but at the same time to be carried out in as short a timeframe as possible. In Ethiopia, 'adaptation' testing program was initiated where introduced promising lines with Ug99 resistance were directly tested in one-year multi-location trials and released for commercial use. In Egypt, both DUS and VCU trials were conducted simultaneously where sometimes they are carried out in subsequent years. Moreover, promising lines were provisionally released for variety popularization and pre-release seed multiplication of later generations (up to registered seed). In Pakistan, promising lines with outstanding performance could be simultaneously entered into different stages of variety trials to expedite the release process for emergency situations. Moreover, the DUS testing can also be reduced to one year to confirm the description, if sufficient descriptive data of the candidate varieties is provided by the breeders.

Although the frequency of resistant lines against Ug99 from NARS was very low, these lines were considered as the first source of material for promotion, since they have been widely tested and seed was already available with NARS (Joshi et al 2011). In addition, a number of elite lines with adequate resistance against Ug99 and with yield advantage of up to 15% have been identified by CIMMYT and ICARDA and were distributed as part of Elite Bread Wheat Yield Trial and Stem Rust Resistance Screening Nursery since 2005 for further testing and release.

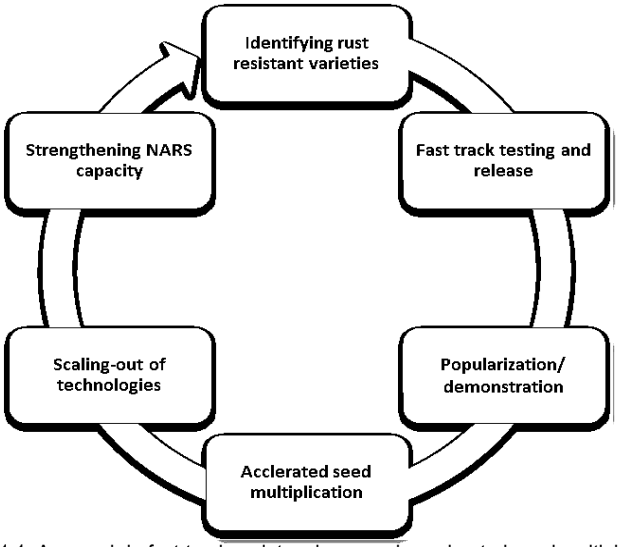

Figure 1.1. Approach in fast-track variety release and accelerated seed multiplication

1.3.3 Variety popularization and promotion

Weak extension services are often blamed for poor transfer of new agricultural technologies to farmers. In all three countries the sheer number of small-scale farmers engaged in wheat production would require doubled effort in number of demonstrations to reach reasonable number of farmers. A variety of approaches were used including regional travelling workshops, national wheat rust workshops, field visits and demonstration plots, field days and print media. NARS made an extraordinary effort in popularizing new rust-resistant wheat varieties to create farmers' awareness and demand for seed. NARS worked with agricultural extension and seed producers in conducting both on-station and on-farm demonstrations to create awareness among policy makers, researchers, seed producers, development agencies, extension services, NGOs and farmers.

1.3.4 Accelerated seed multiplication

There are two critical stages in seed multiplication along the pathway from variety release to getting the new varieties to farmers' fields: small-scale early generation seed multiplication (breeder seed to basic seed); and large-scale seed multiplication (basic seed to certified seed). Availability and access to basic seed of new varieties is often cited as

major impediment for quicker seed delivery to farmers. Fast track variety testing and release system therefore should be linked with accelerated seed multiplication in moving rust-resistant wheat varieties from research plots to farmers' fields as quickly as possible.

A target for rapid seed multiplication should aim to cover at least 10% of the wheat production area. In most countries this was accomplished within three to four generations. Osborn and Bishaw (2009) outlined the systematic approach and planning for accelerated seed multiplication for quick replacement of rust susceptible varieties where national programs can follow the principles and procedures for wheat seed production described by van Gastel et al (2003).

a) Early generation seed multiplication

A flexible approach of 'pre-release' seed multiplication was initiated to overcome the legal and technical hurdles of early generation seed production. As a result multi-location variety trials, pre-release seed multiplication and variety popularization were carried out simultaneously (Figure 1.2). Seed multiplication was initiated much earlier to assure that at the time of release sufficient quantities of basic (foundation) seed are available for large-scale seed multiplication and eventual distribution to farmers. The project provided direct support for pre-release seed multiplication of breeder, pre-basic and basic seed in target countries. Moreover, NARS continue to carry out variety maintenance and early generation seed production once varieties were officially released for commercial production.

In Egypt and Ethiopia, pre-release seed multiplication was carried out strictly by NARS. In Pakistan, pre-release seed multiplication was carried out both by NARS and public and private seed companies under the umbrella of Foundation Seed Cell program. The basic (foundation) seed produced under pre- and post-release multiplication was made available to: (i) formal public and private seed sectors; and (ii) farmer/community-based seed initiatives for further multiplication under accelerated conditions both during main/off-season production.

b) Large-scale certified seed multiplication

The pre-and post-release accelerated seed multiplication by NARS was closely linked to large-scale certified seed production to replace rust

susceptible varieties in high risk areas. In Egypt, the Central Administration of Seed Production (CASP) had early access to foundation seed to accelerate registered and certified seed multiplication. In Ethiopia, basic seed was provided to the Ethiopian Seed Enterprise, Regional Seed Enterprises (ASE, OSE and SSE), public state farms (Bale SF) and Private Estate Farms, development partners (AGRA) and NGOs engaged in farmer-based seed production. In Pakistan, accelerated seed multiplication was implemented with a number of seed companies from both the public (Punjab Seed Corporation), and the private sectors.

c) On-farm seed production

Apart from formal seed production through public and private sector, an alternative farmer based seed production was initiated in Ethiopia and Pakistan. In Ethiopia, a partnership was developed with district Bureau of Agriculture in districts with Agricultural Growth Program where farmers were identified, trained, fields clustered, and provided with seed of new rust-resistant varieties to produce and market the seed locally through formal or informal channels. A revolving seed scheme was established and implemented where farmers return the initial seed for further use by the project. In Pakistan, individual pioneer farmers or groups in rainfed areas of Punjab, Baluchistan and Khyber Pakhtunkhwa were identified and provided with seed of new rust-resistant varieties in areas where the formal sector operation is rather minimal. At least three networks of seed producer groups were initiated and linked with Barani Agricultural Research Institute, Cereal Crop Research Institute and National Institute of Food and Agriculture.

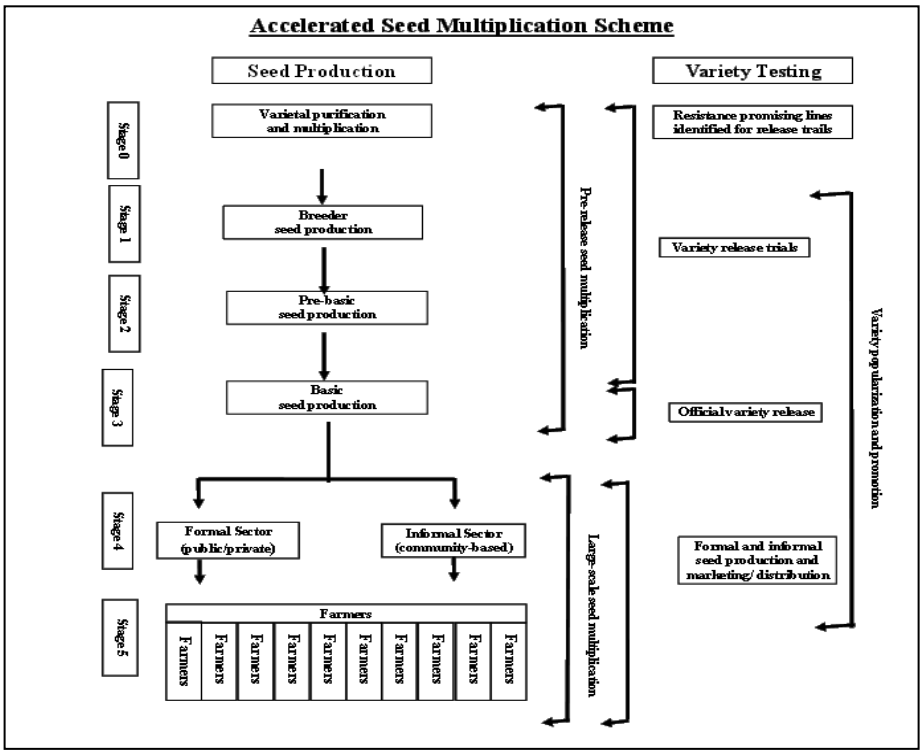

Figure 1.2. Accelerated seed multiplication scheme (Osborn and Bishaw, 2009)

d) Strengthening capacity for seed delivery

Rapid seed multiplication of large quantities of seed will require capacity building beyond the ongoing normal seed activities at country level or regional level. This emergency situation brings more work to an already limited infrastructure to undertake a huge task of both pre-release and large-scale seed multiplication where time is an essence of all operations. Apart from efficient use of existing resources and facilities additional investments may be necessary particularly for robust response to the crisis situation.

Strengthening infrastructure for NARS and stakeholders: In a well-functioning seed system, availability of basic (foundation) seed is a norm than an exception for immediate commercialization of the variety upon its release particularly in the private sector. In public NARS, because of least vested interest, there is disconnection between variety release and its commercialization. Lack of financial and physical resources such as land, equipment, and irrigation, risk avoidance (variety not released), lack of

clear mandate, etc. are some of the constraints observed for the activity to remain ad-hoc instead of a regular feature of NARS program. It is important that a functional seed unit established and equipped with adequate physical, financial and human resources. It would be useful to institutionalize a sustainable early generation seed production for countries to adequately respond to any future emergency situations or normal operations.

Strengthening capacity of human resources: Seed production requires specific knowledge and practical experience to produce high quality seed of high standards of varietal purity and physical, physiological and health. From the outset, assistance in capacity development of NARS and national seed programs is a key to enhance their technical and managerial capacity. Short-term trainings were conducted in principles and techniques of variety maintenance, seed production, seed processing, and seed quality control for technical managers, technicians and farmers whereas workshops aimed at policy and decision makers and senior managers to create awareness of rust problems and contingency planning.

1.4 Partnership with key Stakeholders

A complete wheat variety replacement is an enormous task in terms of millions of hectares to be covered and the quantity of certified seed required for planting by small-scale farmers in developing countries. Large-scale varietal replacement can only be achieved with the full participation and partnership of the key stakeholders in the respective countries. A multi-stakeholders forum was initiated and partnerships established with the Ministries of Agriculture and its affiliated departments such as the agricultural research institutions, agricultural development and extension services, public and private seed companies, variety registration and seed certification agencies, NGOs and farmer associations to create awareness and define their roles, responsibilities and commitments (Figure 1.3). A high level national steering committee and technical committee were established for guiding the project planning and implementation. The project was implemented through a consultative process where each year work plans are prepared at the beginning of the season, activities implemented and monitored during the season, results reviewed at the end of the season and adequate planning made for the next season involving key stakeholders. This had helped in

overcoming some policy and regulatory constraints that would hinder fast track variety release and accelerated seed multiplication to make available seed of new rust-resistant varieties to farmers. The key stakeholders and their roles are as described below:

CGIAR and NARS: It is important that new wheat varieties should combine rust resistance with better agronomic performance such as high yield and acceptable grain quality to induce farmers to adopt. ICARDA and CIMMYT developed the promising lines and distributed them as part of Elite Bread Wheat Yield Trials (EBWYT) and Stem Rust Resistance Screening Nurseries (SRRSN) as part of international nurseries network.

Federal (national) and/or regional agricultural research centers of respective countries undertook fast track testing and release of the new rust-resistant wheat varieties and earnestly engaged in pre-release and post-release seed multiplication to make available sufficient quantities of basic seed using both the main and off-seasons where feasible. This include Agricultural Research Center in Egypt, EIAR (federal) and RARIs (regional) in Ethiopia and federal (National Agricultural Research Center) and several provincial (Ayub ARI, Barani ARI, Cereal Crops RI, Regional ARI, etc.) agricultural research institutes in Pakistan.

Public and private seed producers: The public and private commercial seed suppliers embrace and multiply pre-basic and basic seed in pre-release seed multiplication working closely with NARS and later produced certified seed of new rust-resistant varieties for commercialization using their own resources. The Central Administration for Seed Production in Egypt; federal (ESE) and regional public seed enterprises (Bale Agricultural SE, Amhara SE, Oromia SE and Ethiopian SE) and private seed companies in Ethiopia; and provincial seed corporations (PSE) and several private companies in Pakistan

Regulatory and certification agencies: These agencies have facilitated the fast track testing and release of varieties and certification of early generation seed multiplied under pre-release seed multiplication. It includes the Central Administration for Seed Testing and Certification (Egypt), Animal and Plant Health Regulatory Directorate (Ethiopia) and Federal Seed Certification and Registration Department (Pakistan).

Agricultural development and extension services and NGOs: The agricultural development practitioners, extension services and NGOs partnered with NARS and the seed companies in demonstration and popularization of rust-resistant wheat varieties. They organized field days using all available means and including their resources. They also played key roles in on-farm seed production and dissemination, for example in Ethiopia. In Egypt, ARC worked with the Central Administration for Extension Services for variety demonstration and the Socio-Economic Research Institute to assess the economic benefits of the new varieties. In Ethiopia the district BoAs and some NGOs (SG2000) played a significant role in popularization and demonstration of new varieties and associated technologies. In Pakistan, NARS worked with the national agricultural extension services and/or directly with progressive farmers in variety demonstration and popularization.

Farmer groups and farmers: Farmer groups and farmers not only passive seed users or hosted demonstration, but also engaged in contractual seed production for the formal sector or local seed production and marketing through informal channels assisting the adoption and diffusion of new rust-resistant wheat varieties.

The main frontline actors however were thousands of farmers who participated in variety popularization and on-farm seed multiplication at various stages of project implementation in different countries.

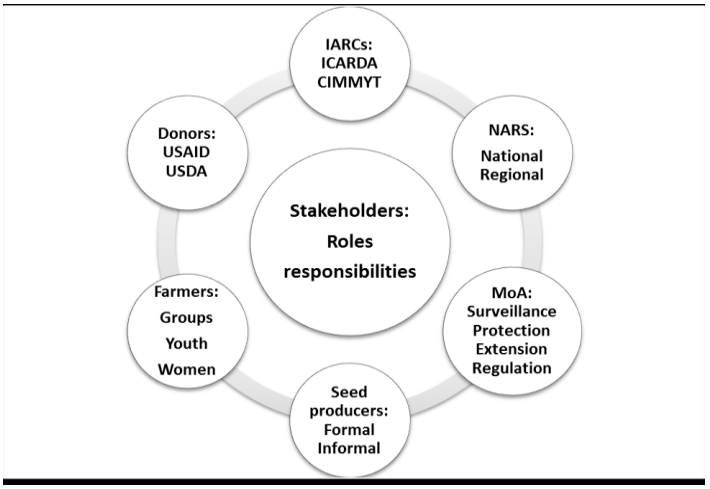

Figure 1.3. Key stakeholders in project implementation

1.5 Project Achievements

ICARDA implemented one regional project entitled 'Accelerated seed multiplication to counter the threat of stem rust in wheat' (Egypt, Ethiopia and Pakistan) completed in March 2012; and follow-up bilateral projects in Ethiopia (Rapid deployment of rust-resistant varieties supported by USAID) completed in December 2014 and in Pakistan (Wheat Productivity Enhancement Program supported by USDA) completed in September 2015, the experiences which are highlighted below.

1.5.1 Accelerated Seed Multiplication to Counter Threat of Stem Rust in Wheat

A geographically broader project jointly developed by ICARDA and CIMMYT and funded by USAID International Disaster and Famine Assistance was implemented from 2008/09 to March 2012. It aimed at fast track testing and release and accelerating seed multiplication to counter the threat of the Ug99 stem rust disease of wheat in countries that lie on the path of potential threat from Ug99. ICARDA implemented the project in Egypt, Ethiopia and Pakistan, and CIMMYT in Afghanistan, Bangladesh and Nepal.

a) Wheat variety releases

The project started with eight promising lines having Ug99 resistance and high yield of CIMMYT and ICARDA origin (Joshi et al 2011). A maximum of 50-100 kg seed each was distributed for further testing and release by NARS in 2008/09 crop season (Table 1.1). In addition promising lines already in the breeding program were also included in the project.

In Ethiopia adaptation testing program led to immediate release of three varieties in 2010 and 2011 from original five promising lines and followed with subsequent release of other five varieties with stem and/or yellow rust resistance over the years. In Egypt one variety each was released in 2009 and 2010 from among the varieties already identified from EBWYT. The variety registration and performance trials were conducted in parallel for the first time which was previously conducted in subsequent years, reducing the timeframe for quick release. In Pakistan, none among the three promising lines distributed were released because

of changes in stem rust dynamics in the country. However, one line with Ug99 resistance identified from EBWYT was released along with other four varieties with confirmed resistance to local stem rust and other rusts. Later on, several wheat varieties resistant to stem (Ug99) and/or yellow rust were released during the project and follow-up projects over the subsequent years (Table 1.2).

Several rust-resistant (Yr, Lr and Sr specifically local strain or Ug99) and high yielding wheat varieties have been identified and released in all three countries from germplasm introduced from IARCs or locally developed by NARS starting from 2009/10 crop season. Two varieties in Egypt (*Misr1 and Misr2*), ten in Ethiopia (*Danda'a, Kakaba, Hoganna, Shorima, Hulluka, Gambo, Hidase, Ogolcho, Biqa and Honqolo*) and seven in Pakistan (*AARI2011, Aas2011, Dahrabi2011, Millat11, NARC2011, Punjab11, PAK2013*) have been released from 2010-2014 (Table 1.2). In, Ethiopia some of the newly released varieties have combined resistance to stem and yellow rusts and yield advantage of up to 21% over widely grown commercial varieties.

Table 1.1 Promising lines distributed (kg) for testing and release in target countries

Promising lines	Origin	Egypt	Ethiopia	Pakistan	Total
DANPHE #1	CIMMYT	-	100	-	100
CHONTE #1	CIMMYT	25	100	300	425
CHEWINK #1	CIMMYT	25	-	-	25
PICAFLOR #1	CIMMYT	-	100	-	100
QUAIU #1	CIMMYT	-	100	300	400
GRACKLE #1	CIMMYT	25	-	-	25
MUNAL #1	CIMMYT	-	100	300	400
Flag 3	ICARDA	-	100	-	100
Flag 5	ICARDA	-	100	-	100
Amir 2	ICARDA	-	100	-	100
Total		75	800	900	1775

Table 1.2. Wheat stem rust and/or yellow resistant varieties released in target countries from germplasm originated from CIMMYT, ICARDA and NARS

Country	Variety	Source	Year of release	Remarks
Egypt	Misr1	CIMMYT	2009	Ug99 resistant
	Misr2	CIMMYT	2010	Ug99 resistant
Ethiopia	Danda'a	CIMMYT	2010	Combined resistance to Ug99 and Yr
	Kakaba	CIMMYT	2010	Combined resistance to Ug99 and Yr
	Gambo	CIMMYT	2011	Combined resistance to Ug99 and Yr
	Hoggana	ICARDA	2011	Combined resistance to Ug99 and Yr
	Shorima	ICARDA	2011	Combined resistance to Ug99 and Yr
	Hulluka	ICARDA	2012	Combined resistance to Ug99 and Yr
	Hidase	CIMMYT	2012	Combined resistance to Ug99 and Yr
	Ogolcho	CIMMYT	2012	Combined resistance to Ug99 and Yr
	Biqa	CIMMYT	2014	Resistance to three rusts
	Honqolo	ICARDA	2014	Resistance to three rusts
Pakistan	AARI2011	Local cross	2011	Resistant to local Sr and Yr
	AAS2011	CIMMYT	2011	Resistant to local Sr
	Dharabi2011	CIMMYT	2011	Resistant to local Sr
	NARC2011	CIMMYT	2011	Ug99 resistant
	Millat2011	Local cross	2011	Resistant to local Sr
	Punjab2011	Local cross	2011	Resistant to local Sr
	Shahkar2013	CIMMYT	2013	Resistant to local Sr
	Pirsabak2013	CIMMYT	2013	Resistant to local Sr
	NIFA Lalma2013	CIMMYT	2013	Resistant to local Sr
	PAK2013	CIMMYT	2013	Ug99 resistant

NB: All newly released varieties were supported through pre-release seed multiplication

Regional variety release: CIMMYT and ICARDA developed set of stem rust resistant varieties and distributed to NARS as Elite Bread Wheat Yield Trials and Stem Rust Resistance Screening Nursery through a coordinated international nurseries network. Most NARS are evaluating similar breeding materials from the CGIAR across regions, with potential for both wide and specific adaptation, where opportunities must be explored for joint or regional release of varieties. From the list of potential promising lines distributed, one can observe 'common' promising lines released in some target countries (Table 1.1). For example, a promising line from 2nd EBWYT was released as *Misr1* in Egypt (2010), but also released as *Muqawim09* in Afghanistan (2009), and later as *NARC2011* in Pakistan (2011). This allowed Afghanistan to import about 151.5 tons of Misr1 seed from Egypt to head-start seed multiplication and distribution in the country. Similarly, Picaflor≠1 was released as *Kakaba* in Ethiopia (2010) and as *Baghlan09* in Afghanistan (2009). Quai≠1 was released as *Gambo* for irrigated areas in the lowlands

of Ethiopia (2011) and Koshan09 in Afghanistan (2009). Danphae was released as *Danda'a* in Ethiopia (2010) and was submitted for release in Nepal (2012). Moreover, Francolin≠1 was released as *BARI Gom 27* in Bangladesh (2012) and as *NL1073* in Nepal

However, this may be a reminder of mega varieties and uniformity of varieties across regions once again raising the concern of vulnerability of wheat to rusts. It is important to maintain the varietal diversity and overcome varietal dominance by identifying and releasing those with comparable agronomic performance and preferred traits at national and/or regional levels. For example in Ethiopia, *Kakaba* was found relatively early maturing fitting to areas with short rainfall patterns whereas *Gambo* could fit well for irrigated lowlands, an area for potential wheat expansion. Attention should be given in diversifying the portfolio of varieties released across the countries to minimize regional vulnerability too.

b) Accelerated seed multiplication

The project played a catalytic role in supporting early generation seed production by NARS and linking that to large-scale seed production by existing public seed enterprise and/or private seed companies. In Ethiopia, both main season and off-season (irrigation for the first time) and low seed rates were used for pre/post-release accelerated seed multiplication of promising lines/varieties in early generation seed multiplication. In Pakistan, NARS and the private sector undertook pre-release and pre-basic seed multiplication under the Foundation Seed Cell program. This enabled to bulk-up sufficient amount of basic (foundation in Egypt) to enter large-scale certified seed production and marketing by the existing public and private sectors. The support by the project enabled for the new varieties to capture over 10% of wheat area envisaged at the end of the project period (Table 1.3).

Early generation seed production: The project initiated pre-release seed multiplication of rust-resistant promising lines identified through IARCs and NARS partnership in order to accelerate the availability of early generation seed while these lines were undergoing variety evaluation for release. A concerted effort was made by NARS and public/private sector to multiply seed of these newly identified promising lines in target countries (Table 1.4). Initially, 10 promising lines in Egypt, eight in

Ethiopia and six in Pakistan entered pre-release seed multiplication in 2008/09. In subsequent years 4 each in Egypt and Ethiopia and six in Pakistan were included in the pre-release seed multiplication. However, with the progress of the project fewer promising lines were included in the program where combined resistance against other rusts was also considered.

In Egypt, 42.23 tons of *Misr1* (22.83 tons) and *Misr2* (19.4 tons) were produced by ARC under pre-release seed multiplication during 2008/09 crop season. The seed produced was used for demonstration and further multiplication. CASP was provided with seed of both varieties and further multiplied producing 288 tons of *Misr1* and 52.5 tons of *Misr2* in 2009/10 crop season. The registered seed was further provided to private seed companies for further multiplication and sale to farmers. There was substantial quantity of seed was made available when Misr1 and Misr2 was released in 2010 and 2011, respectively.

In Ethiopia, both the main and off-seasons were used to shorten the time and maximize the availability of sufficient quantity of basic seed stock through pre-release seed multiplication. About 91 tons of *Danda'a* (29.35 tons), *Kakaba* (43.01 tons) and *Gambo* (19.55 tons) was available following the off-season seed multiplication upon the release of these varieties in 2010 and 2011 compared to the minimum requirement of 50 kg breeder seed for release. The seed of *Danda'a* and *Kakaba* produced during the off-season was used by KARC and provided to federal (ESE) and regional (ASE, OSE) public seed enterprises, public state (Bale) and private estate (Tinsae) farms and on-going projects (Alliance for a Green Revolution in Africa and Sasakawa Global 2000) for further multiplication and demonstration. About 478.53 tons of seed of the two varieties were produced during the next main season.

In Pakistan, three NARC selected promising lines from 2nd EBWYT already in NUYT and registration trials and another three lines from CIMMYT in different stages of variety testing were identified as potential for accelerated pre-release seed multiplication. However, while stem rust (Ug99) is a great concern it was emphasized that resistant to new local Sr race taken into account while evaluating the promising lines. All promising lines (23.584 tons) were dropped except one (0.2 tons and resistant to Ug99) and five more (three from NARS crosses and 2 from

CIMMYT) were included with known resistance to local Sr race and other major rusts. About 991.261 tons of seed was available in 2011 upon the release of *AAR11* (292.435 tons), *Millat11* (8.54 tons), *Punjab11* (580.586 tons), *Aas 2011*(106.2 tons) and *Dahrabi 2011* (0.5 tons). The seed was produced by NARS and public and private seed sector under the umbrella of Foundation Seed Cell program with the approval of FSCRD.

Although, large number of promising lines entered pre-release seed multiplication every year, limited number of varieties was released and the seed produced was advanced for further multiplication. NARS continued with regular early generation seed production of officially released varieties during the course of the project contributing to overall certified seed production (Table 1.4).

Table 1.3. Pre-release seed multiplication of promising lines in target countries in 2008/09-10/11 crop season

Country	No of lines multiplied[1]	No of lines added	Area planted (ha)	Seed produced (t)	No of varieties released[1]	Amount of seed available (t)	Remarks
Egypt	10 (3)	4	21.14	85.166	2	42.23	
Ethiopia	8 (5)	4	110.52	154.79	6 (3)	91.91	Main and off-season
Pakistan	6 (3)	6	330.3	991.26	6 (1)	991.26	
Total	24 (11)	14	389.7	885.766	13 (4)	738.91	

Note: [F]igures in parenthesis are promising lines initially distributed by CIMMYT or ICARDA whereas the rest were identified through regular breeding program from germplasm of NARS or IARCs.

Certified seed production: The basic (foundation) seed produced under pre-release seed multiplication by NARS or by the public and/or private sector directly entered large-scale certified seed production. The partnership enabled the seed suppliers' to get early access to seed of new varieties and accelerate large-scale certified seed production. The linkage and partnership of NARS and commercial seed suppliers enabled to bring seed of new varieties to farmers' fields in the shortest possible period of time.

In Egypt, an estimated 19,840 tons of certified seed of new rust-resistant varieties was produced by public and private sector and distributed during the three years of the project. This amount of seed had the potential to plant close to 11% of Egypt's wheat area, generating a substantial increase in wheat grain production in that country.

In Ethiopia, the production of over 33,423 tons seed of two new rust-resistant varieties by public sector enterprises was sufficient to plant over 12% of its total wheat area during the project period. There was substantial increase on the amount of certified seed of rust-resistant wheat varieties distributed during the project period and after increasing wheat production and productivity in the country.

In Pakistan, a total of 89,306 tons seed of five rust-resistant bread wheat varieties were multiplied by private and public sector entities in quantities sufficient to plant close to 10% of the wheat area. This substantial area covered by rust-resistant varieties improved wheat production and productivity and enhancing food security in target countries.

Table 1.4. Amount of certified seed of new rust-resistant wheat varieties produced in target countries

Country	New rust-resistant varieties (year released)	Amount of seed distributed (tons)		
		2010/11	2011/12	2012/13
Egypt	*Misr1* (2009) and *Misr2* (2010)	566	7,947	10,760
	Total certified seed wheat distributed (17 varieties)	39,622	51,365	53,376
	% certified seed of new varieties	1.4	16	20
Ethiopia	*Danda'a* and *Kakaba* (2010)	758	5,622	27,043
	Total certified seed wheat distributed (33-41 vars.)	27,086	38,736	71,078
	% certified seed of new varieties	2.81	15	38
Pakistan*	*AARI11, Millat11, Punjab11, NARC11* and *Dharabi11* (2011)	2287	42,750	44,269
	Total certified seed wheat distributed (16-20 vars.)	311,805	251,908	171,915
	% certified seed of new varieties	0.73	17	26

*Note: *In Pakistan, only NARC2011 is Ug99 resistance and NARS focus on local stem rust, yellow and leaf rust resistance; number of varieties (vars.) of certified seed varies from year to year*

Pakistan initiated VBSEs in rainfed areas where the formal seed system has limited penetration and farmers may not have access to newly released rust-resistant varieties because neither the public nor the private sector is interested in seed production of these varieties in rainfed areas. As a result, farmer-based seed multiplication was initiated in rainfed areas of Punjab and Khyber Pakhtunkhwa provinces. Preliminary analysis of on-farm seed production and marketing showed on average a net profit of \$348 ha^{-1} which shows better profitability in seed business than grain production.

c) Variety demonstration

New rust-resistant varieties were popularized along with recommended agronomic packages to demonstrate the economic potential. In Egypt, Wheat Research Department popularized *Misr1 and Misr2* working with CAAE (Central Administration for Agricultural Extension) and CASP in conducting both on-station (first year) and on-farm demonstrations (subsequent years) to create awareness among policy makers, researchers, extension services and farmers. In total 275 demonstration plots (2.1 ha) were planted in 24 governorates covering over 203 districts by ARC. In addition 64 field days were organized using seed production fields by CASP from 2009/10 to 2011/12. About 16,258 researchers, extension agents and farmers attended the field days.

In Ethiopia, variety demonstration (0.1 ha) was carried out by EIAR's Technology Demonstration and Scaling-up Program and other development projects like AGRA and SG2000. In 2010, 219 demonstrations were planted in Amhara (81), Oromia (58) and South (80) and Tigray regions by EIAR under the project and a total of 970 participants attended the field day (Asnake, 2012). The two varieties (*Danda'a* and *Kakaba*) were demonstrated on 144 farmers (0.25 ha each) by KARC and on 108 farmers by the AGRA project. Moreover, SG2000 reported that it planted demonstrations in 28 FTCs and with 1097 farmers where 680.79 tons of rust-resistant wheat varieties were produced and about 11,231 farmers were benefitted from informal farmer to farmer seed exchange (Gebretsadik, 2012).

In Pakistan, the popularization and demonstration was minimal until the set of new wheat varieties with stem rust resistance were confirmed by NARS. In 2010/11 about 15 demonstrations were carried for one variety, but nearly 81 demonstration plots were planted focusing on newly released varieties in 2011/12 crop season. In total about 3250 farmers attended the field days.

Farmers hosting the demonstrations were advised to save and use or share the seed with neighboring farmers to facilitate adoption and diffusion of the newly released varieties and serve as nodal diffusion points outside the formal sector. The demonstration has created awareness among farmers and a huge demand as witnessed by requests from farmers. The

popularization and demonstration efforts enabled to bring seed of new rust-resistant wheat varieties to the farmers' fields even before varieties were officially released (e.g. *Misr2* in Egypt) and certified seed was produced through a regular program. This is a tremendous achievement and behavioral changes responding to emergency situations where existing laws, norms and procedures remain sacrosanct.

d) Assessing economic returns

In Egypt, the Agricultural Economics Research Institute investigated the economic returns of Misr1 and Misr2 varieties on farmers' fields with technological packages in demonstration plots (DP) and neighboring farmer's fields (NF) on grain yield, production costs, and net benefits in 2009/10 crop season Some governorates were selected in coordination with ARC to target DP and NF and a random sampling procedure was used to select farmers. Detailed data on management practices, production costs, inputs, yields and returns were collected and summarized below.

The study showed that average grain yield for Misr1 was 5.65 tons ha^{-1} in NF (n=35) and 7.05 tons ha^{-1} in DP (n=63), an increase of 24.9%. The total estimated return was about L.E 6929 and 5606 (@ L.E. 5.945 = UDS 1) in demonstration and non-demonstration fields, respectively with estimated net benefit of L.E. 3945 in demonstration fields, an increase of about 46% compared to non-demonstration fields (L.E 2702). The benefit/cost ratio was 2.32 for new variety (*Misr1*) in demonstration fields while it was 1.93 in non-demonstration fields.

Average grain yield for Misr2 was 5.52 tons ha^{-1} in NF (n=31) and 6.7 tons ha^{-1} in DP (n=52) showing an increase of 21.3%. The total estimated return was about LE 6597 and 5576 in DP and NF, respectively. The estimated net benefit was LE 3643 in DP, an increase of about 39.2% compared to NF (LE 2617). The benefit/cost ratio was 2.23 for *Misr2* in demonstration fields while it was 1.91 in non-demonstration fields. The recommended package for Misr1 and Misr2 in demonstration fields appeared to be productive and profitable and could be adopted by the farmers.

e) Strengthening infrastructure of key stakeholders

Early generation seed production require specialized field equipment such as plot planters, plot harvesters, small seed cleaners/treaters for timely operations and appropriate facilities like irrigation, and cold storage for main or off-season seed production. In order to strengthen such activities modest equipment (tractors, laser levelers, threshers) and vehicles were purchased and provided to NARS on case by case basis. In Pakistan farm machinery (4 tractors, seed drills, rotavators and threshers each and two levelers) were provided to AARI, BARI, NARC and RARI and three mobile seed cleaners were provided to support the network of farmer-based seed producers linked to NARS (BARI, CCRI and NIFA). Moreover, three vehicles were also provided to NARS for project implementation, one each for Egypt, Ethiopia and Pakistan.

f) Strengthening capacity of human resources

Seed production requires specific knowledge and practical experience to produce high quality seed of high standards of varietal purity and physical, physiological and health. From the outset, assistance in capacity development of NARS and national seed programs is a key to enhance their technical and managerial capacity. Short-term trainings were conducted in principles and techniques of variety maintenance, seed production, seed processing, and seed quality control for technical managers, technicians and farmers whereas workshops aimed at policy and decision makers and senior managers.

Regional workshop: In September 2011, a regional workshop on Variety Identification and Maintenance was organized by ICARDA, ESE and EIAR in Ethiopia. The workshop served as a forum for the three target countries to:

- Share experiences on innovative procedures for fast track variety release and accelerated seed multiplication and dissemination of new rust-resistant varieties;
- Provide technical knowledge on variety release processes (performance and registration trials);
- Variety maintenance and early generation seed production; and
- Establish partnerships for continuous collaboration on rapid release and dissemination of varieties.

- Twenty five scientists and technical staff from the three countries, Ethiopia (15), Egypt (5), and Pakistan (5), attended the workshop.

Regional travelling workshop: In April 2010, a two-day regional workshop was organized by ICARDA, FAO and ARC in Egypt as part of contingency planning to counter the threat of Ug99 for participants from seven countries: Egypt, Ethiopia, Iraq, Saudi Arabia, Sudan, Syria and Yemen. Thirty five participants visited ARC research stations, CASC variety registration trials and CASP seed multiplication fields to familiarize themselves with activities related to Ug99.

National workshop on wheat rusts: In Egypt, annually a one-day national wheat workshop was organized and accompanied by national travelling workshop for staff from agricultural research, department of agriculture, extension services, seed producers and farmers to keep abreast with new developments and progress of the project. About 364 participants attended the workshops from various stakeholder institutions covering several themes by ICARDA and NARS partners during the project period.

In-country courses: Several in-country hands-on practical training courses were organized for agricultural research, seed sector and extension staff focusing on wheat rust diseases, seed science and technology, and wheat production. About 444 staff has received such short courses during the project implementation phase in 2010 and 2011.

Rust surveillance and contingency planning: ICARDA also contributed and shared the experience to national and regional rust surveillance and contingency planning workshops conducted for North Africa, Central and West Asia under the FAO umbrella.

International conferences: Three senior researchers each from Egypt and Pakistan attended an international yellow rust conference in 2010 at ICARDA, Aleppo Syria. In another development 19 senior seed program managers from the public and private sector staff from Egypt, Ethiopia and Pakistan attended a regional seed conference in 2009 and 2010 in Turkey.

g) Variety release and seed marketing

ICARDA initiated a case study on variety release mechanism in Egypt,

Ethiopia and Pakistan. The main purpose is to analyze the issues that arise in variety release and to make recommendations for 'good practice' that may be useful to those who manage the variety release system. The synthesis covered the full range of activities that occur from the identification of promising lines by the breeder until early-generation seed is available for multiplication and providing recommendations for good practices. In Pakistan, ICARDA organized in 2012 a national consultation meeting on the draft report and broader issues on seed production systems that highlighted the need to strengthen public-private partnership in research, create new and more effective seed legislation, and improve the capacity of all partners in the country's seed sector. Moreover, case studies on wheat seed marketing were also initiated and final reports were prepared in Ethiopia and Pakistan.

2.5.2 Rapid Deployment of Yellow Rust-resistant Varieties in Ethiopia

In 2011, a new ICARDA-EIAR joint project supported by USAID was launched (2011-2014) in response to 2010 yellow rust epidemics in the country. The project, built on the experiences of USAID Famine Fund, was to rapidly deploy high-yielding and yellow rust-resistant wheat varieties. The project broadened its scope including both stem and yellow rust-resistant varieties and focused on four thematic areas with focus on strengthening the national wheat breeding program's capacity to develop rust-resistant varieties and fast-track their testing and release; popularization and demonstration of rust-resistant varieties and associated technologies; accelerated seed multiplication (pre-release, post-release and certified seed production) during the main and off-seasons by existing public and private sector; on-farm seed production and marketing directly working with farmers in target districts of Agricultural Growth Program; and strengthening the infrastructure and human resources capacity of stakeholders.

The project has established a functional platform of broad range of partners and stakeholders which include federal (EIAR) and regional (AARI, OARI, TARI) agricultural research institutes; federal (ESE) and regional (ASE, OSE, SSE) public seed enterprises and private seed companies; public and private state farms involved in seed production; federal (MoA) and regional extension and input directorates; farmer seed

producers associations and Farmers' Cooperatives Union; and farmers/seed users.

a) Wheat varietal releases

The project provided substantial support to the National Wheat Research Program, at KARC in fast-track testing and releasing of new rust-resistant varieties. The main activities include introduction and evaluating international nurseries, crossing and evaluating segregating population from national breeding program and conducting variety yield trials and verification trials of candidate varieties for release. In 2014, four candidate varieties were presented by KARC, among which *Honqolo* (for high rainfall areas) and *Biqa* (for dry areas) were released by the NVRC. The seed of these two new varieties was multiplied during the off-season and the main season and become available to public/private seed producers for large-scale multiplication by 2015/16 crop season.

The procedure was also adopted by other on-going wheat projects in Ethiopia such as SARD-SC and EAAPP where additional varieties were released and their seed multiplication was accelerated.

b) Early generation seed production

The project linked NARS with commercial seed producers and supported the accelerated seed multiplication of recently released and existing rust-resistant varieties during the main and off-season and 7,013 tons basic seed produced and provided to public seed enterprises and private sector (private seed companies, cooperatives and farmer seed producer associations) from 2011/12 to 2014/15 crop season to produce certified seed for distribution to farmers. Eight farmer seed associations, one federal and three regional public seed enterprises and public and private seed producing farms and new emerging private sector were provided with seed.

c) Large-scale certified seed production

Availability and access to basic seed regularly has enabled large-scale certified seed production. A significant achievement has been made where certified seed of rust-resistant wheat varieties were produced and distributed through partnerships of the public and private sector. For example, about 31,078 tons (32% new and 14% old varieties) certified seed of rust resistant wheat varieties from a total wheat seed supply of

59,810 tons in 2013/14 crop season. Similarly, about 55,071 tons (60% new and 18% old varieties) certified seed of rust resistant wheat varieties were distributed from a total wheat seed supply of 70,738 tons in 2014/15. The certified seed of new and existing rust resistant varieties is sufficient to plant an estimated bread wheat area of 207,187 ha and 398,733 ha during the 2013/14 and 2014/15 crop seasons, respectively. This enabled quick and rapid deployment of new rust resistant varieties in farmers' fields. This is sufficient to plant an estimated bread wheat area of 207,187 ha and 398,733 ha during the two seasons. This enabled quick and rapid deployment of new rust-resistant varieties on farmers' fields.

d) On-farm seed production

Apart from direct support to formal sector operations of NARS and partnership with public or private seed enterprises, the project aimed to bring seed directly to target districts under Agricultural Growth Program working with farmers and district agricultural office (Figure 1.4). A group of 100 farmers were identified in selected *kebele* administration in each target district, clustered in adjoining fields, provided with seed of rust-resistant varieties sufficient to plant 0.25 ha. Farmers, and development and extension agents were trained on technical aspects of seed production and linked to regional seed inspection services to ensure seed quality.

Three approaches were used with the seed produced after participating farmers return in kind the amount of seed provided by the project and retain the 10% of the seed produced for own use; farmer's groups collect, process and market the seed under their own management; farmers are linked to FCU's which purchase seed from farmers and market the seed to their members and non-members; or farmers directly linked to PSEs (ASE, OSE and SSE) which purchase the seed and market it in respective and neighboring *woredas*.

Farmers returned the seed as a revolving fund, kept some for own use and sold excess seed to other farmers through informal channels or formally through cooperatives or PSEs. The revolving seed fund was used to reach more farmers through similar approach by the Office of Agriculture.

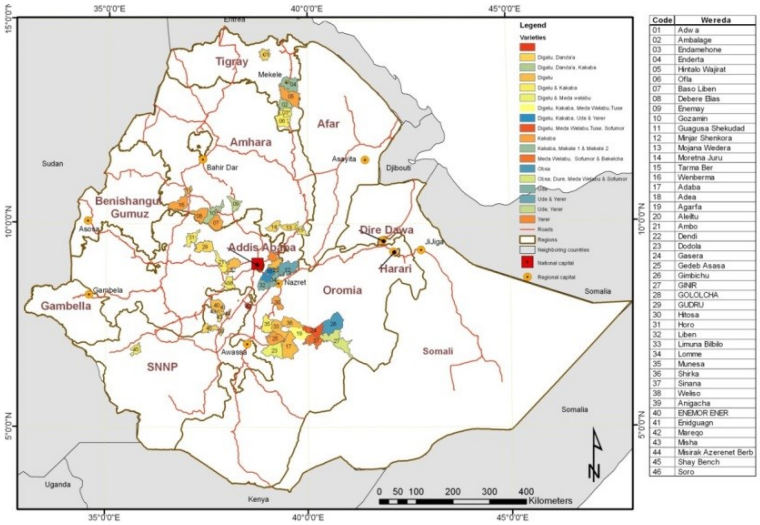

Figure 1.4. Target district for on-farm seed multiplication and dissemination

In four seasons the project distributed 894 tons of seeds through, which covered 7,095 ha producing 26,615 tons of seed/grain sufficient to plant 177, 433 ha. The project reached 19,631 farmers (out of which 12% were female) benefiting 100,751 household members in four major wheat production regions (Figure 1.5 and Table 1.5). In some target districts 80% of wheat area is planted with yellow rust resistant varieties. The multiplier effect will be considerably higher as part of the produce was used as seed for planting purpose in subsequent years. This would lead to substantial area coverage with Ug99 and yellow rust-resistant varieties.

	
Guagsa Wonberima District, West Gojam Zone, Amhara region	Dendi District, West Shewa Zone, Oromia region

Figure 1.5 Farmer seed producers

Average yields over four seasons were 3.8 tons with the highest of 7.8 tons on farmer's fields. The average estimated net income from rust-resistant varieties is varying from $50 to $200 depending on area planted by wheat. Given that the estimated total land area covered with new stripe rust-resistant wheat varieties at around 400,000 ha, the net returns from these improved varieties will be in the range of $20-80 million.

e) Scaling out of wheat technologies

The project also provided support to regular technology scaling out activities of EIAR in some target districts following the same modalities of on-farm seed production. The project directly distributed 261 tons seed through scaling out which was planted on 2,182 ha producing 7,758 tons of seed/grain potentially sufficient to plant 51,720 ha. The project directly reached 12,500 farmers (out of which 8% were female) benefiting and estimated 65,610 household members in four major wheat production regions (Figure 1.5 and Table 1.5).

f) Emergency seed relief

Emergency seed relief was provided to farmers affected by yellow rust in 2010 in Arsi and West Shewa zones and by the new stem rust strain in 2014 in Bale zones. A total of 120 tons were distributed and 813 ha was planted producing 2317 tons of seed/grain sufficient to plant 15,525 ha (Table 19). About 3799 farmers have direct access to seed benefitting 22,794 household members. The same process of on-farm seed production was used except that farmers were not required to return the seed to the revolving fund.

g) Durum wheat value chain

In Ethiopia, bread wheat production dominated the landscape, but it is highly vulnerable to periodic epidemics of rust diseases. Durum wheat appeared to be less vulnerable to stem rust and yellow rust. The project aimed at reviving durum wheat production to tackle the rust problems and diversify wheat production and at the same time create the producer-market linkage with the agro-industry. A durum wheat value chain workshop was organized on 17 June 2014 and attended by participants drawn from relevant wheat value chain actors including representatives of flour mills and pasta and macaroni factories.

Eight pilot districts were identified to initiate both seed and grain production of two durum wheat varieties. Member farmers of primary cooperatives were identified, organized and trained as durum wheat seed producers or grain producers. About 19.93 tons of seed was distributed for seed production to 208 farmers (18 female farmers) and planted on 170 ha. An estimated 547.2 tons was produced for distribution to durum wheat grain producers; and the amount is sufficient to plant 3,648 ha in 2015/16 crop season. The seed produced will be collected and marketed collectively or through farmer cooperative unions to their members for grain production in 2015/16 crop season.

Another 51.75 tons seed was distributed to 712 farmers (65 female farmers) and planted on 407.2 ha for durum wheat grain production. An estimated 1592.2 tons of durum wheat grain will be produced in 2014/15 crop season. Farmers produce durum grain as per the requirements of the industry which will be aggregated and sold through unions to the different factories based on contractual agreement. The grain will be aggregated (minimum 40 tons), sampled and tested at least for protein quality, gluten content, moisture content and hectoliter weight to determine the price based on the quality. The contractual agreement between the unions and factories will be signed and the samples will be collected and tested following harvest time. It is envisaged to expand the activities in the coming years including more farmers' cooperatives and unions across the country.

Table 1.5. On-farm seed production with farmer groups

Items	On-farm seed production	Scaling-out	Emergency seed	Value chain	Total
Seed distributed (t)	894	261	120	72	1347
Area planted (ha)	7095	2,182	813	577	10667
Estimated production (t)	26615	7,758	2317	2139	38829
Total farmers reached	19631	12500	3799	920	36850
% female farmers	12	8	2	9	8
Beneficiary HHs	100,751	65,610	22,794	5,520	194,675

h) Demonstration

The project also supported EIAR's pre-extension demonstration in major wheat production regions. Field days were organized at district level using Farmer Training Centers, demonstration plots and on-farm seed multiplication fields to create awareness and demand for seed of new

rust-resistant varieties released over the project years. In these events farmers from participating and neighboring districts, development agents, extension workers, researchers and regional, zonal and district level administrators and policy makers participated. Annually the project supported one field day each in four regions. In 2011/12, in addition to *Danda'a and Kekeba* two new bread wheat varieties, namely; *Shorima* and *Hulluka* were demonstrated in 41 districts where four farmers per district were provided with seed of the two varieties i.e. 164 demonstrations. The project sponsored four field days in Oromia (Horro), Amhara (Wonberima), SNNP, and Tigray where over 700 farmers, development agents (DAs), extension workers and farmers participated in the farmers' field days. In 2012/13, four field days were sponsored in four districts in Amhara (Guagusa Shikudad and Tarmaber), Oromia (Agarfa) and SNNP (Mareko) where 1180 (5.8% female) farmers participated. In 2013/14 crop season, three new bread (*Hidase, Hoggana* and *Ogolcho*) and two new durum (*Mangudo* and *Mukiye*) wheat varieties were demonstrated at FTCs in 41 districts. Four field days were supported where 3,895 participants attended of which nearly 10.1% were female participants. In 2014/15, the activity is extended to 51 districts reaching more farmers in irrigated lowland areas. In addition to recent releases four new bread (*Biqa, Honqolo, Mandoyu*, *Sanate*) and one durum (*Mukiye*) wheat varieties were demonstrated at FTCs. About 400 demonstration fields were planted with newly released rust-resistant varieties both by the support of the project and national program.

i) Strengthening infrastructure and capacity

Substantial investment was made to strengthen the facilities and infrastructure and human resources capacity of NARS and key stakeholders during the project period.

Infrastructure: In order to upgrade the infrastructure, two heavy duty tractors, levelers, planters, ridgers each with spare parts were purchased and distributed to key NARS. A seed storage facility at KARC, and seed quality laboratory (KARC and DZARC) was supported and 14 sewing machines and 150,000 polybags of different size was purchased and used for branding EIAR basic seed production. Moreover, given the scale of field operations at federal and regional levels, one station wagon, five pick-ups, one minivan and two automobiles were provided to NARS.

The project provided three mobile seed cleaners, one each for seed producers in Oromia (Haqo Sado Farmer's Seed Producers' Cooperatives in Dodolla); Amhara (Dil Betigil Farmers Seed Producers Cooperatives in Womberma) and Tigray (Ayiba Birhan Farmer's Seed Producers' Cooperatives in Embalaje) Regions. The seed producer cooperatives were trained in the operation and maintenance of the machine and will be monitored for its effective use and their performance in seed production.

Human resources: The project created awareness of wheat rusts both at managerial and technical levels. Policy makers and senior managers participated both at international and national workshops whereas the technical staff attended regional and in-country courses.

Workshops and conferences*:* The project inception workshop was attended by 72 participants from federal and regional NARS, public seed enterprises and Bureau of Agriculture; private seed companies in May 2011. A first round of national consultation meeting was carried out with heads of districts offices of agriculture and extension agents from 30 September-1 October 2011 where 46 participants attended the meeting to clarify the purpose and objectives of the EIAR-ICARDA Seed Project. A second round of two-day consultation meeting was organized on 29-30 February 2012 at Adama for Oromia and Southern regions and on 6 March for Amhara and Tigray regions (26 districts) and was attended by *Woreda* Agriculture, Extension offices and Administration. Each *woreda* reported on area planted, seed produced, number of farmers (male and female) participated in seed production, number of field days conducted and farmers participated, performance of rust-resistant varieties and farmer's perception, challenges during work plan implementation. The primary task of the meeting was to discuss the modalities for seed procurement (PSEs, FCUs or informal diffusion) and based on lessons learned plan activities for next main season. A workshop was organized and attended by 80 participants drawn from relevant wheat value chain actors including representatives of flour mills and pasta and macaroni factories.

Training courses**:** Both regional and in-country courses were organized for key stakeholders in quality seed production. Accordingly, six participants from TARI and SARI and agricultural input experts from Amhara, Oromia and SNNP (6 participants) attended the seed production

and marketing training given in Egypt (2012) and three seed experts each from RC participated in variety maintenance and quality seed production and seed certification courses in 2012 and 2013 in Egypt.

Each year farm managers and seed production experts from federal and regional research centers were trained in seed production technology to ensure quality breeder and pre-basic seeds production to be distributed to basic seed producers (Table 1.6). In addition training of trainers were organized in four regions for subject matter specialists (SMS), agricultural experts and development agents (DAs) of district BoA prior the planting time to assist the on-farm seed production. Training of DAs and model farmers were also undertaken in some districts who can demonstrate the technologies in their respective

Table 1.6. Number of participants in-country courses

Target groups	Number of trained personnel				Total
	2011/12	2012/13	2013/14	2014/15	
SMS and DAs*	270 (35)	410 (45)	370 (75)	440 (67)	1490 (222)
Farm Managers	50	45	35	40	157
Others		24	36	27	87
Total	320	479	441	507	1734

Note: Numbers in parenthesis are female participants

Project communication: The project leaders from NARS attended and presented the achievements to the annual FARA meeting (Ghana) international rust conference (Turkey). A short video on describing the activities undertaken and farm level impacts on the livelihoods of farmers were produced and circulated to all stakeholders in Ethiopia, USAID and CGIAR community.

1.5.3 Wheat Productivity Enhancement Program in Pakistan

The Wheat Productivity Enhancement Program (WPEP) project aimed to enhance and protect the productivity of wheat in Pakistan by supporting research that leads to the identification, adoption, and optimal agronomic management of new, high yielding and disease-resistant wheat varieties. Accelerated seed multiplication is one of the components of the project.

In Pakistan the wheat seed system appears diversified with involvement of both the public and private sector in the Punjab except in other

provinces and dryland areas. However, availability of early generation seed remains a constraint in commercialization of new varieties in the country. Within the WPEP project which focuses on developing Ug99 resistant varieties, a modest budget was allocated for accelerated seed multiplication. A greater effort was made in accelerated seed multiplication of early generation seed (pre- and post-release) and linked to large-scale certified seed production by formal (public and private) and informal sectors in disseminating Ug99 resistant varieties.

The following were achieved during the two years of implementation (2011/12-12/13)

- 436 tons seed of promising lines were produced under pre-release seed multiplication (44 tons of exclusively 20 Ug99 resistant promisingly lines); one variety was released in 2013 and seed become available both to public and private sector;
- 2170 tons seed of early generation produced by NARS, public and private sector for further multiplication and distribution (104.4 tons exclusively Ug99 resistant varieties); and
- 494 tons seed produced from demonstration, popularization and on-farm seed production of new rust-resistant (164.8 tons exclusively Ug99 resistant varieties). From yield data, the estimated net return of \$227 ha^{-1} was achieved when seed of new varieties is sold as seed instead of grain.
- In dryland areas most of the varieties released were not multiplied by the formal sector due to weaker demand and expected low yields. Neither the public nor the private sector was interested in producing and marketing the seed in the dryland areas. The project initiated on-farm seed production with farmers through a support provided by NARS partners. About 284 tons seed of new and existing commercial varieties was produced with farmers in dryland areas of Punjab and KPK with average net returns from seed sales of \$337/ha.

After 2013/14-14/15, under the ICARDA-CIMMYT agreement, efforts were made in promoting and multiplying Ug99 resistant bread wheat varieties i.e. NARC 2011 and PAK 2013.

- 67.063 tons seed of promising lines in NUWYT's were produced under pre-release seed multiplication by 8-10 NARS partners from federal and provincial agricultural research institutes;

- 1020 tons seed of early generation produced by NARS (47.68 tons exclusively of Ug99 resistant varieties) and provided to public and private sector (40 seed companies) for further multiplication and distribution;
- Source seed of NARC 2011 and PAK 2013 was distributed to various federal and provincial agricultural research institutes (11 research institutes sufficient to plant 12.55 ha), public and private sector companies (40 companies on 31.97 ha) and farmers (102 farmers on 41.28 ha) in 2014/15 crop season to expand the seed production and distribution of Ug99 resistant wheat varieties;
- The project partnered with local NGO National Rural Support Program with membership of 400,000 farmers for diffusing Ug99 resistant varieties;
- The project initiated regular variety maintenance program at NARC for early generation seed production;
- The project provided emergency seed for internally displaced people in tribal areas due to flooding in 2014;
- Training in seed production technology and quality assurance was provided to 60 technical staff drawn from relevant seed sector stakeholders and 150 famers involved in local seed production

The project was able to partner with NARS and formal seed sector to quickly multiply and disseminate seed of not only of Ug99 resistant varieties but also to local stem rusts (Table 1.7). This enabled producing early generation seed production by NARS in partnership with FSCRD which was exclusively the activity of the public seed corporations.

Table 1.7 Amount of early generation seed produced during 2011/12-2014/15 crop seasons

Institutes	2011-12	2012-13	2013-14	2014-15
NARS	222.7	382.8	358.4	184.9
Public seed sector	677.3	876.9	1153.9	421.6
Total	900.0	1259.7	1512.3	606.5

Some of the key issues emerged from the project activities include the following:

- Pre-release seed multiplication of promising lines and post-release early generation of released varieties become institutionalized by NARS by engaging FSCRD in seed quality assurance. Pre-basic and basic seed production was exclusively used to be handled by public seed sector;
- Despite the diversity of wheat seed sector in the country, the performance of the formal sector in delivering seed of farmer preferred varieties still remain

problematic in dry areas and other provinces with exception to Punjab. A concerted effort is required to strengthen alternative strategies to reach farmers in drylands and remote areas; and

- The development and promotion of Ug99 resistance varieties must be combined with comparative yield advantage over the existing commercial varieties. An attempt to disseminate NARC2011 and PAK 2013 across all provinces showed mixed results both from seed producers and farmers. A diversified portfolio of rust-resistant varieties needs to be developed and disseminated to meet farmer's demand and to avoid vulnerability to rusts.

1.6. Project Coordination and Implementation

1.6.1 Guiding principles

Several guiding principles underpin the project implementation to guarantee the goals and objectives are achieved. These principles are based on shared values and trust of stakeholders. The project's guiding principles can be summarized as follows:

- The project strengthened local resources (human, institutional, physical, etc.) for the benefit of partner institutions;
- The project preserved and strengthened local knowledge and technologies in its work with plant genetic resources and farming practices;
- The project was mindful of multiple dimensions of sustainability i.e., genetic diversity in farmers' fields to ensure long-term environmental sustainability; and
- Project planning, research, and technology development and dissemination occur in the context of partnership networks, taking advantage of the comparative advantages and skills of different institutions working in the agricultural sector of target countries

1.6.2 Project coordination

For project coordination establishment of innovation platforms facilitated by the high level Project Steering Committees and Project Technical Committees are used across projects with some variations in respective countries. In Ethiopia, multi-stakeholders platforms were established at federal and regional levels (Amhara, Oromia, South and Tigray Regional States). These include federal and regional NARS; public and private seed enterprises; bureaus of agriculture, agriculture inputs and extensions, Farmer's Cooperative Unions and farmers.

ICARDA provide leadership and coordination of the project while EIAR was an implementing partner of the project. The steering committee consisted of five representatives from ICARDA, EIAR, and USAID was established to provide guidance in project implementation. In addition, an overall coordinator and thematic area coordinators were identified and assigned to implement the project

The project identified three major thematic areas including generation of new varieties through fast track testing and release, accelerated seed multiplication, and popularization and scaling up/out of rust-resistant wheat varieties. An overall project coordinator and three project thematic area coordinators were identified and were assigned by EIAR to play coordinating and facilitating roles in all project activities. At a regional level, a focal person was identified from Extension/Input Department of Bureau of Agriculture who coordinates the activities in respective regions. In addition, to oversee the logistics in technology distribution and multiplication a focal person in each district (woreda) was assigned facilitating project implementation.

Functionally, the platform operates at strategic and operational level bringing together different federal and regional research, seed sector and development stakeholders along the value chain. At strategic level the project has Project Steering Committee (composed of ICARDA, EIAR and USAID senior management) and Project Technical Committee (project coordinators and technical staff from ICARDA and EIAR). These was supported by regional and district level forums operated by focal persons of respective institutions.

1.7 Lessons Learnt

From the outset the project focused on key thematic areas in its implementation process. However, no two wheat seed systems are exactly the same regardless of any apparent similarities. The configuration of institutions involved in research, seed delivery, extension services, reflects unique characteristics of each country. However, there are recurring patterns of moving varieties from agricultural research stations to farmers' fields where different laws and polices need to be navigated in each country during the process of project implementation. The project is also unique in addressing an emergency

situation where each country went through its own experience in responding to these challenges.

The following are some of the lessons learned during project implementation process:

- Availability of a mechanism for international collaborative variety testing established under the BGRI umbrella where both IARCs and NARS participate to evaluate their materials against Ug99 and its variants in Kenya and Ethiopia;
- Fast track variety release achieved through a 'crash' program in which elite germplasm from IARCs were selected for accelerated release following a single year of adaptation testing at multi-locations by NARS notably in Ethiopia;
- Popularization and demonstration of newly released varieties and/or promising lines to create awareness among farmers and key stakeholders to facilitate their adoption and diffusion;
- Accelerated pre-release seed multiplication of promising lines to produce sufficient amount of basic (foundation) seed before release of varieties. Pre-release seed multiplication occurred during the off-season notably in Ethiopia and in Pakistan involved the private sector under the Foundation Seed Cell program;
- During the fast track testing and accelerated seed multiplication, some varieties have been released in different countries. This may lead to predominance of mega varieties and uniformity of varieties across regions once again raising the concern of vulnerability of wheat to rusts. It is critical to maintain the varietal diversity and overcome varietal dominance by identifying and releasing those with comparable agronomic performance and preferred traits at national and/or regional levels;
- Partnerships engaging multiple stakeholders brought on board policy makers and regulatory agencies to facilitate flexible approaches to fast-tracking variety release and accelerated pre-release seed multiplication to achieve more timely response to rust threats;
- Availability of funds sufficient to support national and international efforts to address the global threat of stem rust both in developing new rust-resistant varieties and their rapid seed multiplication;
- A global network of variety testing and sharing data among advanced research institutes, IARCs and NARS accelerated the release and delivery of improved varieties in the region, for example seed of *Misr1* was shipped from Egypt to Afghanistan;

- Partnerships with private seed companies proved to be the quickest and most cost effective strategy for multiplying and delivering seed of rust-resistant varieties in some countries; and
- Senior leaders oversaw the planning and coordination for rapid seed multiplication with an effective partnership among stakeholders

1.9 Concluding Remarks

Wheat rusts remain a major challenge where the durability and longevity of resistance is short lived threating food security nationally, regionally and globally. The emergence of new races of rust and its potential for long distance spread with devastating consequences remain a big challenge and with no room for complacency. This situation would be exacerbated with emerging issues and the consequences of climate change. There is a need for state of preparedness and contingency planning at country level with broader participation of key stakeholders defining their clear roles and responsibilities. There is a need for policy makers to be aware for an immediate action and make available the necessary resources required for the effective management of rusts. This may embrace from establishing adequate surveillance and monitoring of rusts to development and deployment of diverse set of varieties through an effective and efficient seed delivery system to counter the threat of wheat rusts.

The project has made significant contribution in creating awareness of wheat rust threats and in establishing a functional platform bringing together the key stakeholders along the wheat seed value chain involving policy makers, development practitioners, and farmers. Several rust-resistant wheat varieties have been developed and deployed to farmers' fields within the shortest period of time using a variety of formal and informal approaches and partnerships at national and international levels. It enhanced wheat production and productivity and ensured food security averting the looming crisis of food security in target countries.

However, the development and deployment of rust-resistant wheat varieties cannot be a one-off or short-term effort. International and national breeding programs must develop a diverse set of rust-resistant wheat varieties over time, as any single form of resistance is expected to be short-lived. Durable resistance depends not in a single variety given

the expected short longevity of rust resistance in wheat but in maintaining the diversity in the resistant varieties deployed to farmers.

References

Bishaw Z and AJG van Gastel. 2009. Variety release and policy options, 565-587. *In* Plant Breeding and Farmer Participation, *In:* Ceccarelli S, EP Guimaraes, and E Weltzien (eds). FAO, Rome, Italy. 671 pp

Chaves MS, JA Martinelli, C Wesp-Guterres, FAS Graichen, SP Brammer, SM Scagliusi, PR da Silva, P Wiethölter and GAM Torre. 2013. The importance for food security of maintaining rust resistance in wheat. *Food security* 5: 157-176

Joshi AK, M Azab, M Mosaad, M Moselhy, M Osmanzai, S Gelalcha, G Bedada, MR Bhatta, A Hakim, PK Malaker, ME Haque, TP Tiwari, A Majid, MRJ Kamali, Zewdie Bishaw, RP Singh, T Payne, HJ. Braun. 2011. Delivering rust-resistant wheat to farmers: A step towards increased food security. *Euphytica* 179:187-196

Osborn T and Z Bishaw. 2009. Principles for rapid variety release, seed multiplication and distribution in developing countries to counter the threat of wheat rust, 179-188. *In:* RA McIntosh (ed.), BGRI 2009 Technical Workshop Proceedings. 17-20 March 2009. Cd. Obregon, Mexico: BGRI. 225 pp

Shiferaw BM. Smale, H.J Braun, E Duveiller, M Reynolds and G Muricho. 2013. Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. *Food Security* 291-317

van Gastel AJG, ZBishaw and BR Gregg. 2002. Wheat seed production, 463-481. *In:* BC Curtis, S Rajaram, and HG Macpherson (eds.) *2002.* Bread Wheat: Improvement and Production. Plant Production and Protection Series No. 30. FAO, Rome, Italy. 554 pp