International Center for Agricultural Research in the Dry Areas

ICARDA

Working Paper

# A strategic plan to revive wheat in Central and West Asia and North Africa by out-pacing *Puccinia striiformis* Westend (yellow rust)

S. Nagarajan and S. Rajaram

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This report provides background and analysis for a proposed research and capacity building initiative to support countries in Central and West Asia and North Africa region to better manage and reduce the threat of wheat stripe rust.

It is part of a body of information and evidence that documents ICARDA's past work and specific expertise in supporting countries to address the threat of wheat stripe rust (yellow rust) in their national and regional food production systems.

**Feedback**

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## EXECUTIVE SUMMARY

### ICARDA's unique expertise in fighting wheat stripe rust

This report provides background and analysis for a proposed research and capacity building initiative to support countries in Central and West Asia and North Africa region to better managed and reduce the threat of wheat stripe rust.

The report is part of a body of information and evidence that documents ICARDA's past work and specific expertise in supporting countries to address the threat of wheat stripe rust (yellow rust) in their national food production systems.

Based on the wealth of published research it has produced and participated in, ICARDA has published a number of unique research and resources on dealing with wheat stripe rust:
(see http://www.icarda.org/research-action-Stripe_Rust_Strategies).

- 'Research to Action' report to brief decision makers, in potentially affected countries, on strategies they can make to manage wheat stripe rust
- Proceedings of ICARDA-organized scientific symposia on wheat stripe rust in Central and West Asia 2004, 2006 and 2010 – a compilation of work by some 100 partners and abstracts presenting new science on the development of stripe rust resistant wheat varieties.

The ICARDA breeding program has been active for three decades and has new produced wheat varieties that are resistant to wheat stripe rust. In addition to developing new varieties, ICARDA works closely with wheat producing countries in North Africa, West Asia, East Africa and Central and South Asia on surveillance and early warning for the spray of stripe rust.

A new partnership being planned between the government of Turkey and ICARDA, is looking to create the world's first rust pathology laboratory that is operational year-round to provide low-income countries with a rapid testing service, for samples sent by countries monitoring their stripe rust risks.

## INTRODUCTION

Since the 1990s the area sown to bread wheat in the Central and West Asia and North Africa (CWANA) region has increased at the expense of other crops. The bread wheat varieties, Attila and Kauz, and bio-similars, dominate in those areas where seed replacement was poor and native varieties of facultative wheat and winter wheat are still dominant. *Puccinia striiformis* westend (Pst) survives on durum wheat, the wild relatives of wheat, and on barley. The pathogen is endodemic as it survives on seedlings that grow from seeds that fell at harvest time, wheat ratoon, and on collateral hosts which serve as green bridges. Year around availability of the main host enables a rapid evolution of the pathogen in response to challenges posed by the host and the environment.

Except for Ethiopia, the CWANA region has interconnected epidemiological zones. If all the zones share common genes in their variety this permits a sweeping spread of Pst. The western disturbance, mid-altitude climatic phenomena enable a gradual spread of Pst virulence from west to east. There are apparently two major centers of pathogen evolution, the Caucasian belt and the Kyrgyzstan area mountain system. The stripe rust (Pst) pathogen will continue to remain the main production constraint of colder regions while all other diseases will be sporadic or of local importance. A new international initiative is suggested to cut down the production loss caused by Pst. This calls for greater coordination between the national agricultural research systems (NARS) of the region, the Consultative Group on International Agricultural Research (CGIAR) institutions, and lead research establishments in other parts of the world.

A new initiative, of ICARDA in partnership with a number of National Agricultural Research Systems (NARS), is planned over a six-year period. Outcomes of this program are expected to be increased capacity of participating national partners to manage the program by themselves over the longer term.

The recommended six program areas are:

- Crop health
- An integrated pest management (IPM) strategy for green crops
- Germplasm development and sharing
- Pre-breeding, biotechnology and genetic resources
- Seed production and on farm knowledge transfer
- Identification of elite lines and basic seed production by the NARS.

The three cross-cutting action areas are:

- Sharing pest surveillance
- Cooperative development of varietals
- Seed production.

Emphasis has been given to winter and facultative wheat improvement with the underlying principle of gene deployment. Durum wheat and barley variety improvement, backed by a sound seed production chain, will promote the creation of a varietal mosaic and thus check Pst. An IPM strategy of plowing in the green bridge, increasing surveillance, patho-typing, resgene postulation for gene deployment to take advantage of the variation in the wheat growing periods, and species diversity has been advocated.

In the CWANA region, greater coordination on seed chain management and policy research and closer interactions with wheat farmers is suggested.

## 1. WHY THE CRISIS?

The hexaploid bread wheat (*Triticum aestivum*) is the second most common cereal grain crop in the world. Any reduction in the global annual wheat production creates a food shortage and increases the price of food commodities, bringing misery and suffering to millions of people for whom wheat is the staple food. Bread wheat is unique amongst cereals and the wheat gluten has amazing visco-elastic properties, making it ideal for several food cuisines, baked products, and specialty foods. For well over a century the focus has been on breeding for high yield, good grain quality, and widely adapted varieties. Long duration winter wheat has a photoperiod and thermo sensitivity from nine to ten months duration. It is grown in northern latitudes or at higher elevations. The chilling requirements of the facultative, long duration wheat are relatively shorter and this is cultivated where Mediterranean type weather prevails. Spring wheat is a short duration post-winter sown crop with high yield potential. In many places of the CWANA region where winter is less severe spring wheat is cultivated during late October to May.

Durum wheat (*T. durum*) is quite common in the CWANA region. The hard yellow grain is used for several extruded products – couscous, bulgar, and in several Italian specialty foods. The other tetraploid wheat, Khapli or *T. dicoccum*, has a hard grain, which is high in protein, and is an ideal health food and substitute for durum as a breakfast cereal, porridge, etc. Several wild species related to wheat, grasses, barley, etc., occur freely in the CWANA region.


*Figure 1.1. The Central Asia region*

## 1.1 Surge in the bread wheat growing area in Central Asia

The CWANA region is a large wheat growing zone with varying climate, seasons, and soil resources. In the CWANA nearly 50 million ha are sown to wheat each year at different elevations and cropping sequences as a rainfed or irrigated crop.

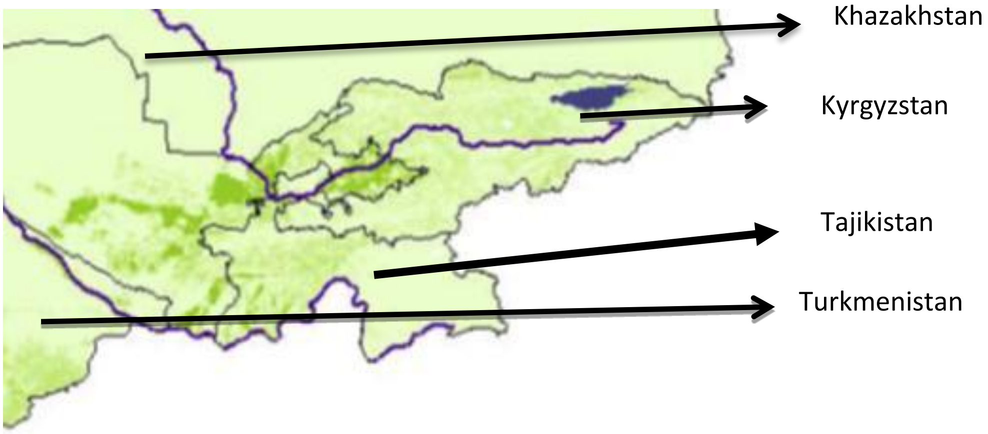


*Figure 1.2 Places where the bread wheat growing area has increased*

Prior to 1987 the Soviet part of Central Asia was a major cotton growing area. Now Central Asia has a number of aspiring young nations – Uzbekistan, Tajikistan, Turkmenistan, Kyrgyzstan, and Kazakhstan. These nations are focused on food security and greater water use efficiency. Since cold desert occupies a substantial part of this region, irrigation water for agriculture is very scarce. In Uzbekistan, Tajikistan, Turkmenistan, and Kyrgyzstan the wheat area has increased. In Kazakhstan the rainfed wheat growing areas was reduced by 1 million ha. In southern Central Asia, 1 million ha under bread wheat was ravaged by yellow rust (Pst) epidemics.

United States Department of Agriculture data shows that Uzbekistan reduced its cotton growing area from 2.1 to 1.4 million ha in 2011 and its rice growing area from 0.15 to 0.03 million ha in 1987. In Central Asia the rice growing area was reduced by 0.11 million ha and the cotton growing area by 1.0 million ha. There was also a reduction of the area given over to fodder crops. The result was that the spatial and temporal barriers for the spread of Pst urediniospores were altered. The crop micro-climate and the self-sown wheat population (the green bridge) tilted the balance in favor of Pst at a time when the wheat in the area was trapped under pan-genetic vulnerability.

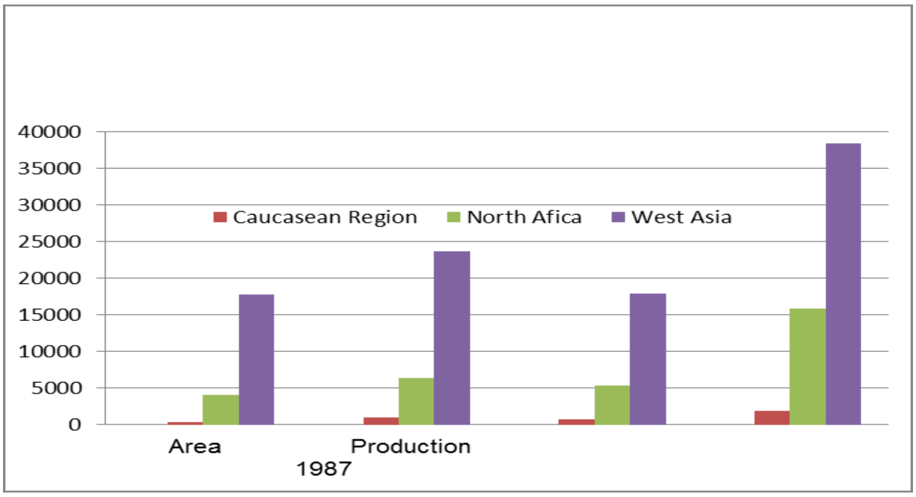


*Figure 1.3. Area (million ha) under wheat production in the WANA region in 2011*

Wheat cultivation in mountainous Caucasia is complex, with widely varying elevations and narrow valleys where all types of wheat are grown. In 1987, Georgia, Armenia, and Azerbaijan together had 0.42 million ha under wheat and this increased to 0.81 million ha in 2011. In Ethiopia, another mountainous terrain, the area under wheat increased several fold in 2011 – from 0.64 to 1.5 million ha. In North Africa (Morocco, Algeria, and Tunisia) the increase in the wheat growing area was minimal – from 3.6 to 4.04 million ha. And in Egypt, the wheat growing area was increased from 0.58 to 1.3 million ha. The new area gained was invariably used for spring wheat. The per ha productivity of wheat all over North Africa increased between 1987 and 2011 – quite significantly in Egypt. But, in Caucasia there was hardly any increase in productivity per ha.

In West Asia (Lebanon, Jordon, Turkey, Syria, Iraq, and Iran) the wheat growing area was 17.8 million ha in 1987 and it remained static till 2011. Possibly, only the varieties being grown changed – Attila, Kauz, and bio-similars. The entire additional growing area in the CWANA region went to spring bread wheat, creating a pan-genetic vulnerability to PstYr9 + Yr27 virulence. The CWANA, including the Caucasus, has a substantial area under barley. The role of barley and other collateral hosts in the perpetuation of and evolution of Pst virulence is yet to be understood.

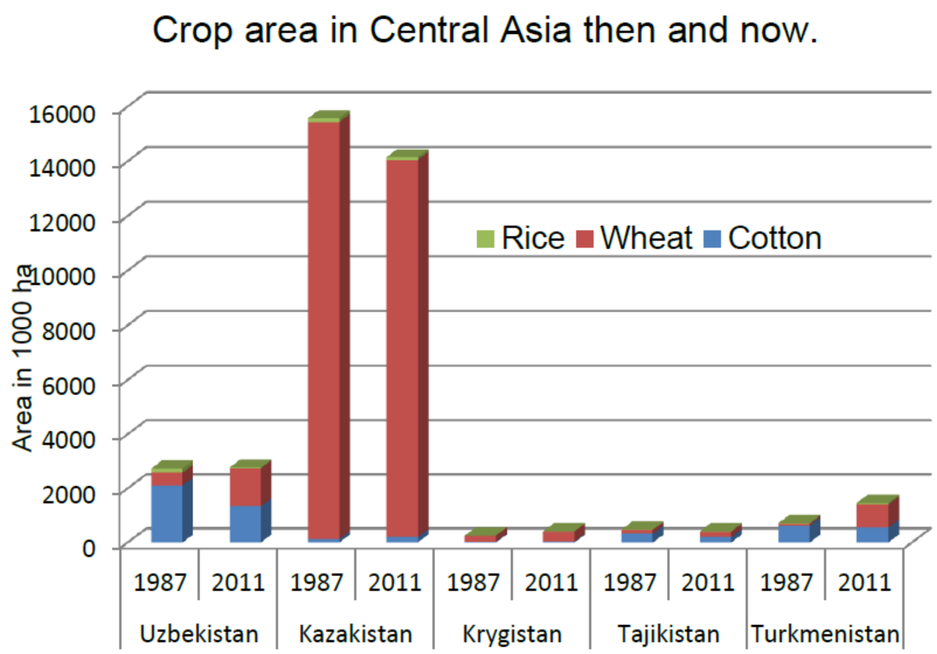


*Figure 1.4. The areas under rice, wheat, and cotton in Central Asia in 1987 and 2011*

In Central Asia 15.0 million ha are sown to wheat, of which winter and facultative wheat account for 5.0 million ha and the rest is spring wheat. In addition, there is a substantial area under barley, and minuscule areas under triticale and collateral grasses. All this information needs to be examined holistically to understand the epidemiology of Pst in the region. As there was no increase in the area sown in the West Asia region the higher productivity recorded was mainly a result of productivity gains. The productivity gain was achieved by replacing old varieties with better adapted, high yielding ones.

**1.2 Directional selection pressure on Pst**

The spring bread wheat, Attila, and the bio-similar with translocation 1B/1R carrying Yr9 + Yr27 have been available since the mid 1990s. It was soon adopted because of its yield superiority and resistance to yellow rust. The wide adoption saw Attila and bio-similars occupy vast areas. The CWANA region already had PstYr9 virulence and soon a PstYr9 + Yr27 combination appeared. The resultant pan-genetic vulnerability to Pst inadvertently created yellow rust epidemics in 2003, 2005, 2009, and 2010 in the CWANA region.

It is well established that the Pst urediniospore could spread 800 km and more during a crop season. And Van der Plank (1984) noted scattered initial infection foci increased the chances of an epidemic. The pan-genetic vulnerability, ready availability of a green bridge for Pst to survive after the wheat harvest, and the early establishment of Pst foci during the crop season promoted the development of a yellow rust epidemic each year.

**In 1982, Van der Plank wrote that 'durable resistance' is a term used in England and is best avoided.**

## 1.3. Aggressive Pst

More recently, Milus et al. (2009) reported that the globally dominant, new Pst virulence shows greater fitness and adaptation to a wide range of weather conditions. This wide adaptability of Pst resulted in the dominance of the virulence in the population. The new Pst virulence, at low temperatures – between 10 and 18$^{o}$C – sporulates sooner, expresses symptoms faster, and produces more spores per mm$^2$ of lesion as compared to the old isolate. Similar outcomes are found under tests conducted at higher temperature regimes of between 12 and 28$^{o}$C. If parts of Asia tend to become cooler, then such an adapted Pst virulence may dominate and create repeated epidemics. Such virulence can sporulate even during the early Fall on volunteer plants/a green bridge, and infect the main crop early in the crop season to trigger pandemics. The new Yr9 + Yr 27 virulence probably has such aggressiveness or 'epidemic potency'.

Slow rusting is not a diagnostic of one form of resistance or the other. There are several cases of incomplete vertical resistance conditioning slow rusting. Van der Plank in 1982 wrote that aggressiveness and virulence and horizontal and vertical resistance are precisely defined terms derived to cover all possibilities within a two-variable system of host-pathogens. The aggressiveness now recorded in the new Pst population matches the horizontal or slow rusting resistance of the host system. In other words, the new virulence of Pst is able to match both vertical and slow rusting or rate-reducing resistance system of the currently popular Attila bio-similars.

## 1.3 Epidemiology got altered

In 2009 in Uzbekistan, both winter and spring were unusually moist and had more than 125% of the normal precipitation. The winter temperatures were above normal and Pst infections were recorded in southern Uzbekistan as early as February 2009 when the crop was in the post tillering-early booting stage. By March/April the epidemic was at a peak while the temperatures were still cool. By the end of April, the build-up of the disease was so high in southern Uzbekistan, adjoining Afghanistan, and Turkmenistan that a huge amount of inoculum moved northwards. Severe crop losses were recorded in Samarkand, Jijax, Syrdarya, and Tashkent. From the heavily infected fields, the roaring combine harvesters might have let-loose clouds of Pst urediniospores making them windborne and able to travel several kilometers before settling on a green winter wheat crop. A south to north movement of Pst urediniospores is the general trend in Central Asia. The arriving spores added to the already available local inoculum in the North, surviving and spreading from the 'green bridge'.

Kazakhstan experiences a Pst epidemic every two to three years. The main focus of Pst is in the south and from there it spreads north, north east, and all over the country. The pattern of Pst movement in Central Asia is different from that in South Asia, where the over wintering Pst in the Himalaya/Hindu Kush glides southwards to the Punjab plains. Initial infection foci appear by early January. By mid to late March, temperatures increase and the disease tends to reach epidemic proportions. This temperature surge during March also poses restriction on the crop, making it mature early and in that process restricts the severe development of Pst.

In Iran, wheat seeds that fell during the harvest geminate and produce plants that serve as a green bridge, making the urediniospores available to the main crop. This happens in cooler pockets at higher elevations in the mountainous terrain where wheat is harvested very late in the year. The Pst can also survive on grasses that act as a green bridge. Latent infections of Pst occur on wheat seedlings during autumn and winter. Sporulating infections have been observed in November in Mazandara and Azerbaijan provinces. In many other provinces, early infections during November to January have been recorded when temperatures were around 15$^{o}$C. In general, spores from over-summering sites infect the newly sown crops before the snowfall begins. Given that the host is vulnerable, yellow rust epidemics in Iran are decided by a continued spell of congenial weather and by the strength of the initial inoculum.

## 1.4 Virulence and effective genes

In the CWANA region, Pst surveillance, collection of yellow rust samples for virulence typing, and maintenance of type cultures are followed to some extent in countries like Iran and Pakistan. A sketchy picture can be generated by stitching together bits and pieces of data generated by foreign projects. In Iran no virulence was observed on lines with Yr1, Yr3, Yr4, Yr5, Yr8, Yr10, Yr15, and Yr18 and on a few other undesignated genes. In addition, in northern Pakistan, Yr17 was effective, but Yr3 was ineffective. In Kyrgyzstan Yr2+, Yr4+, Yr5, Yr10, and Yr15 were moderately resistant.

Since 1920, India has been conducting in a systematic manner virulence typing of the *Puccinia* spp. that infects wheat. This data is a very valuable resource base and may yield useful information on pathogen dynamics.

## 1.6. Weather and climate change

There is lot of anxiety that the global climate is undergoing a change and that pandemics may occur. In fact, a dramatic change in climate may not happen, but aberrant weather is expected at odd times. This may alter the running mean temperature of a given location. For example, Ludhiana, India, is located in the heart of the productive wheat growing plains of northwest India. Analysis of the ground level minimum temperatures, maximum temperatures, and rainfall over 35 years (1970 - 2004) showed that there was no change for any of these three parameters. But when the information was divided, on the basis of the two main crop seasons – as *Kharif* (monsoon season) and *Rabi* (mild winter season) – then a change in climate was clearly evident. There was a small, but not significant, increase of 0.08$^{o}$C/year in the minimum temperature and a decrease of 0.02$^{o}$C/year in the maximum temperature. In general, the *Kharif* season rainfall increased by 9.5 mm/year. In the *Rabi* season there was no significant trend in the rainfall pattern. Both the crop seasons recorded increased minimum temperatures and it is not clear if the rapid expansion in irrigation and large-scale adoption of a rice/wheat farming system contributed towards this increase. Climate change happened in a small way in the northwestern plains of India and the reason why it happened is unclear.


*Figure 1.5. Track of the western disturbance influences on the spread of Pst in Central and West Asia*

The winter precipitation over Northwest India that favors Pst is governed by the mid-altitude level macro weather pattern called the ‘western disturbance’ (WD). Periodically low pressure systems, originating around Black Sea area, are formed during the non-monsoon months and they slowly move towards the Indian Himalaya. In that process they bring rain, snow, and cold spells to the Middle East, South and Central Asia, and northern parts of South Asia. The WD route has been correlated with the yellow rust epidemic in South Asia and the spread of the new Pst virulences. Any increase in the frequency/strength of the WD affects rainfed wheat; it brings more rain and predisposes the crop to Pst, leaf blotch (*Septoria tritici*), and head scab (*Fusarium nivale*).

### 1.7. Role of NARS

The NARS in the CWANA region have research and development institutions of differing capacities and capabilities. As there are a score of official languages in the region, transactions are carried out in English, which is a limitation. Communication, coordination, training, and creating a common technical platform to check Pst often are exasperating. The field and laboratory facilities need capital investment coupled with a scaling-up of talent. Non-integration of Central Asian nations with the world's scientific community has led to their dependence on international institutions for the supply of elite wheat lines. Substantial efforts are needed to develop institutional capacity in the region, if, in future, the NARS of the CWANA region are to manage the wheat disease problems themselves.

### 1.8 Brief action plan

The wheat diseases calamity in CWANA is a very serious one and needs to be addressed through a consortium/mission type of program. A well designed CWANA regional program, undertaken in close partnership with well-established institutions, will be required to achieve a sustained growth in wheat production. To address this issue, the new initiative needs to be structured as a network linking several institutions, clients, and funders located in different parts of the world. In other words, what is required is an inter-country program involving advanced research laboratories working on *Puccinia.* It is suggested that the organizations participating in such a program would include CGIAR institutions, NARS, non-government organizations (NGOs), seed companies, and national governments. In this multicultural region, a pre-project activity is recommended to forge a cooperative program with a common objective and desire to control wheat diseases and enhance production. This new initiative for the CWANA region could be led by a Coordinator.

## 2. THE NEW INITIATIVE – SIX PROGRAM CIRCLES

### 2.0 Project landscape

A new initiative is proposed to contain the Pst epidemic in the CWANA region. This new initiative visualizes a multi-disciplinary global network, based on regional needs. It has been designed to harness the collective wisdom for effective problem solving. The documentation can form the basis for winning funds for the project as a whole or can be subdivided to frame stand-alone projects. The new initiative has two streams of flow. One is a science-centered program circle in the six thrust areas. These circles are intrinsically linked, overlap with each other, and have to be dealt with holistically. There are regional issues that cut across the circles and this two way mapping will avoid duplication of efforts and develop area-specific prescriptions. The cross-cutting program will include sharing pest surveillance information, common crossing blocks, cooperative varietal evaluation, seed production, technology refinement and adoption, and capacity building of the NARS.

After the near catastrophic situation arising from repeated Pst epidemics on Attila bio-similars in the CWANA region (including the Caucasus) it has become necessary to re-examine the wheat programs of the region. There is a disconnect between the wheat breeding and the rust management strategies in the region. The fractured infrastructure of the new Central Asian republics, the unsatisfied desires of the Arab spring, and the increases in food prices call for a new initiative to rejuvenate wheat production in the CWANA region. A strategic alliance involving NARS, ICARDA, donors, governments, and seed companies is suggested under the new initiative.

***The disconnect between wheat breeding and disease management strategy in the CWANA region is too obvious.***

The paucity of local knowledge on the epidemiology of Pst, the absence of regular patho-typing and disease surveillance information, poor IPM backup, changing cropping patterns, etc. have made the variety centric wheat production strategy unsustainable. Area-specific resistance gene deployment and positioning resgene combinations differently in spring wheat, facultative wheat, and winter wheat offer new opportunities to contain Pst. Planned germplasm use and anticipatory disease resistance breeding by the NARS, using marker assisted selection, would rejuvenate the plant breeding efforts. Several such efforts in seed production, participatory technology transfer, and capacity building of the staff are required to trigger the resurgence of wheat production in the region.

## 2.1 Program structure

Shared but differentiated program circles – one each for North Africa (including Ethiopia), the Caucasus and West Asia, Central and South Asia – are necessary. There will be a certain degree of shared work responsibility, but accommodating local needs has to be the cardinal principle.

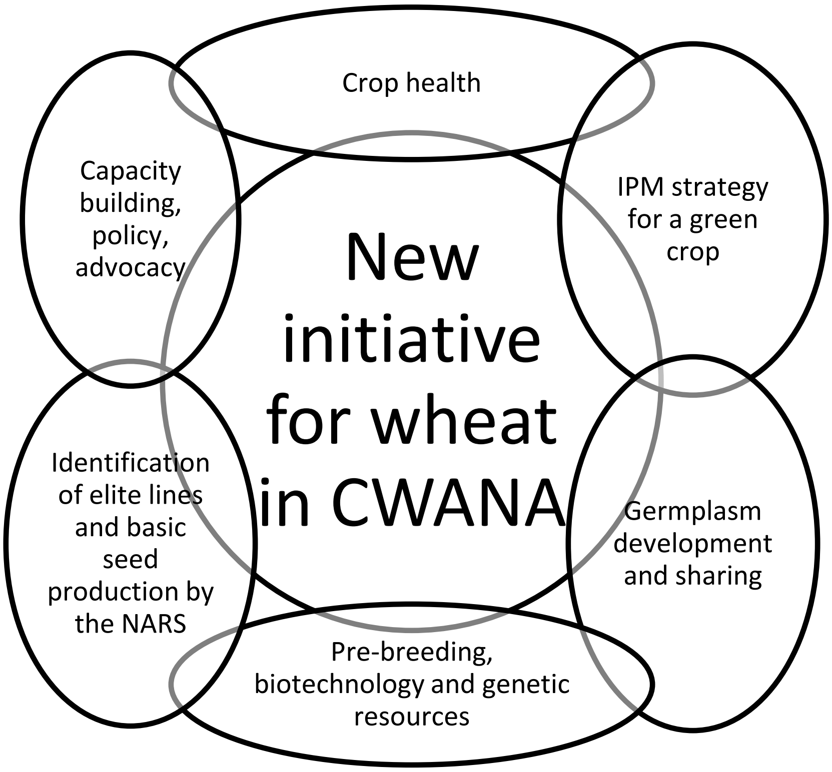


*Figure 2.1. The program circle and the six thrust areas*

The program circle (PC) is interconnected like a chain to enable cross party discussion and strategy planning. The interlinking webs will be for North Africa, West Asia and the Caucasus, Central and South Asia. Communications between the PCs can be through drop box, mail, and annual discussion and these can be designed once the mission Coordinator has been appointed.

## 2.2 Command and control

The Yellow Rust (YR) Coordinator would be the operational head of the plan. He should be a member of the lead institution, have functional autonomy, and be answerable to the ICARDA management. The budget will be with the host institute and the Coordinator could have executive powers delegated by the governing body.

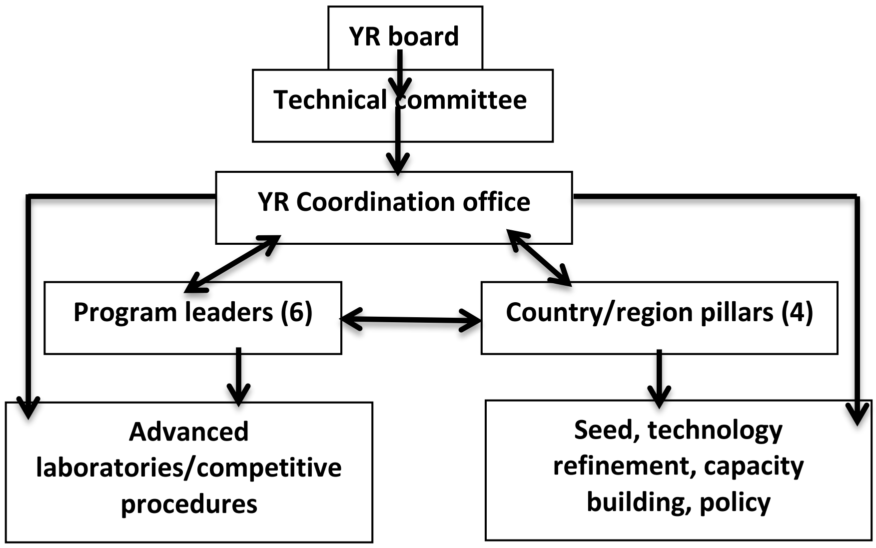


*Figure 2.2. Organogram for the new initiative*

An independent board, with a chairman and members drawn from concerned institutions, would act as the members of the Governing body. The Coordinator would submit financial, administrative, and technical achievements to the board and seek annual grants from it. Assisting the Coordinator would be six research leaders who would act as nerve centers for the program. To harmonize the efforts within the region the research leaders would draw upon a procedural framework. Periodic work planning meetings, quick data and information sharing procedures, and participatory technology transfer efforts would cut across the PC activities. Following a competitive procedure, work in a specific domain would be outsourced. Issues, such as the identification and characterization of novel resgene, development of specific software for data compression and analysis, etc., are potential activities for competitive assignment. Special consultants would be engaged to undertake target-outcome evaluations, review the outputs, redefine the objectives as needed for midcourse corrections, suggest new experimental tools and procedures, etc.

Under the proposed plan, bread wheat (spring, facultative, and winter), durum (winter and spring), *dicoccum*, other *Triticum* spp., barley, and triticale are to be covered. All of them are hosts for Pst and, thus, the group is to be tackled holistically to contain pandemics.

# 3. CROP HEALTH

The proposed strategic plan has six interconnected program circles to ensure the smooth flow of information between them. Within each program circle several activities have been identified. Such an open ended, flexible program is necessary as the CWANA is not a homogenous tract and ground realities vary quite considerably.

## 3.1 Crop health and vigilance

Several pathogens and insect pests infect wheat in the CWANA region and, during favorable years, Pst epidemics occur reducing the yield to 40%. Such severe epidemics affect the quality of the harvested grain, which results in reduced market prices and inflicts economic hardship and misery on the growers. The CWANA region is quite diverse, but the boundaries of the epidemiological zones have become merged because of the widespread cultivation of Attila, Kauz, and bio- similars. The mega-epidemiological zone created by the wide spread cultivation of Attila and Kauz bio-similars favored repeated pandemics in the CWANA region. Under the new initiative, several actions are to be initiated and can be implemented in a coordinated manner. Some of these actions addressed in the Crop health circle are detailed below.

### *3.1.1 Survey and surveillance*

In about six or seven uredinio-cycles from the time the initial focus of the Pst infection gets established on a recently sown wheat crop, it reaches a high terminal disease severity. The purpose of the early field survey is to locate the initial infection focus and assess whether it will spread further. By putting all the pieces of information together, an assessment can be made on the epidemic potential. The CWANA, apparently, is composed of five Pst epidemiological zones and epidemics vary between them for several reasons.

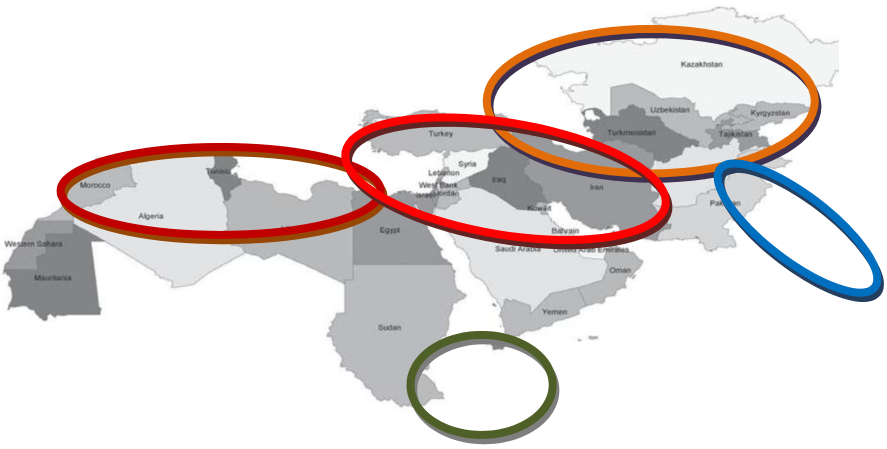


*Figure 3.1. Epidemiological zones of Pst in the CWANA region*
*(Three important epidemiological zones of the CWANA region are indicated in three shades of red. Other zones are indicated by rings of a different color)*

It is recommended that roving surveys be conducted, the first at about the tillering stage, the second at booting time, and the third a fortnight after flowering. It is quite likely that for each epidemiological zone the correct 'catch survey' period can be identified. The number of stops needed to record disease prevalence and severity will depend on the total area under wheat on that route. In dense wheat growing areas it is recommended that frequent halts be made to inspect the health of the crop. Electronic notes and GPS- based survey recordings would transmit scanned pictures to a data base. The pictures would be appraised by a plant pathologist before the scouted information was accepted. Survey staff must be conversant with sampling procedures, how to record prevalence and disease severity, the coefficient of infection, and the area under the disease progress curve.

For not easily accessible locations, the presence of *Puccinia* urediniospores can be monitored by simple wind-vane based spore traps. Microscopic examination of the sticky tape of the air sampler would reveal the number of rust spores present above the canopy level. Based on the spore catch count, a relationship between spore count in the air sampler and the ground level disease severity can be established. If the correlation is sound, then, based on the spore count in the sampler, the possible disease severity in the crop canopy can be inferred.

Remote sensing of disease severity from a space-borne platform is another modern approach. The meteorological satellite, METSAT, facilitates short-term weather forecasting and ground level weather data conditions. Crop phenology information, disease severity prediction using the CERES model, and crop assessment, can be gathered by a resource satellite. Putting all this information together will provide a reliable disease forecast. Use of the 'eye in sky' can be perfected for making routine crop health assessments and yield prognoses.

### *3.1.2 Static survey*

Trap nurseries can be designed for each zone with a set of commercial varieties, selected resgenes, link lines with other zones, and collateral hosts. In all, a trap nursery can be formed from not more than thirty lines. Each line can be sown in two rows, 2 m long, surrounded by three rows of a susceptible border. Each epidemiological zone must design its own trap nurseries and plant them at strategic locations.

## 3.2 Crop health vigilance

On the strength of the survey information and on the basis of the predicted short-term weather forecast, a prognosis can be issued on the extent of Pst severity that is likely to prevail in the following days. In the event of a prediction that Pst would exceed 5% severity, then immediate prophylactic action should be taken. If uninterrupted linear disease severity is expected, then spraying the crop immediately with a systemic fungicide may be necessary, as delayed spraying will not have the necessary results.

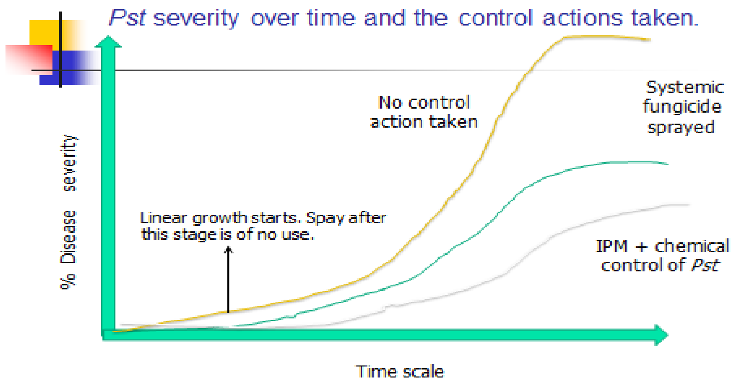


*Figure 3.2. Pst severity over time and the appropriate control actions to be taken*

### 3.3 Field sampling and virulence typing

The methods to be used for surveying, collecting a field sample, preparing it for laboratory evaluation, assessing the virulence of a set of differentials, and characterizing the reaction pattern, demand skill. Therefore, the staff concerned must be equipped with the knowledge, experience, and materials to do this laborious work. Virulence typing in the CWANA region is not well organized and there is considerable scope to improve it under the new initiative. For the CWANA region, one good cooperative rust patho-typing and breeding for resistance facility should be created to serve the entire CWANA community.

Highly qualified personnel are required for multiplication of inoculum on zero hosts, virulence typing, detailing a virulence formula, gene postulation, and other such activities. It is also imperative to ensure continuity of the personnel. The initial and advanced yield trial material should be seedling evaluated and the probable resgene present in the test entry can be postulated to execute the gene deployment strategy. Teams of plant pathologists engaged in virulence typing and resgene identification must closely interact with plant breeders, if the shared dream of checking the epidemic potential Pst in the region is to be realized.

### 3.4. Resistance screening

A live type culture of all available virulences must be maintained under good plant pathology practices. Each year, active plant breeding centers should obtain the reference inoculum, multiply it, and field inoculate the spreader rows. The constitution of the spreader row, field design, creating epiphytotic levels, and scoring severity and reaction type may vary with each epidemiological zone. Therefore periodic, centralized orientation courses need to be designed to energize the breeding for rust resistance programs.

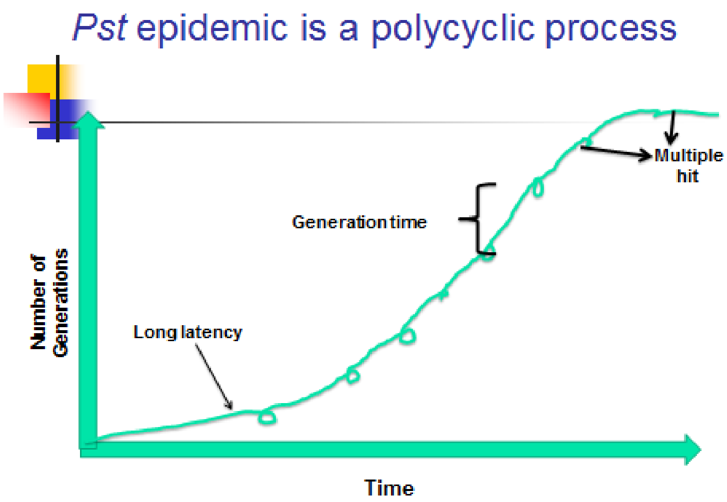


*Figure 3.3. Polycyclic process of a Pst epidemic*

The very Pst goes in to long latency if the post infection temperatures are cold and the pustules bust open when congenial weather conditions return. The mycelium of the pathogen proliferates, becomes systemic within that leaf, and, when favorable weather returns, produces long stripes of uredia. The long latency is partially compensated for by over production of urediniospores to allow for the drag suffered by long latency. Long latency is also induced by the host against the pathogen as a component of the rate reducing or slow rusting resistance, but no compensation occurs as in the other case.

In some cases, seedlings show a susceptible reaction to Pst, but produce on the flag leaf an intermediate reaction or 'X' type of pustules. The host plant often interferes with the life tablestage of the pathogen, extending the generation time taken by the pathogen. Very often, by the time the crop ripens the terminal disease severity is less and below the economic threshold. Such adult plant resistance (APR) is governed by poly genes and is additive in action. There are several exceptions to this rule of thumb in the Sr, Lr, and Yr genes system. The classical example is Sr 2, which is recognized as an APR gene. Such APR genes can be combined with known seedling resistant genes, such as Yr3, Yr4 or Yr5, and, in a good agronomic background, can have long field life against Pst.

The APR genes, like Sr2, enhance the latency period and reduce the terminal disease severity by reducing the rate at which the disease severity increases. This rate-reducing resistance results in production of the MR/MS type of pustule and, thereby, interferes with pathogenesis. Some of the resistance gene expressions are temperature sensitive and change from ; to 3++ under warmer temperatures. The reverse is also true with some other genes. Therefore, a plant health program in association with genetics should do the phenotyping of the host-virulence-temperature interaction for a clearer use of these genes in variety development.

## 4. IPM STRATEGY FOR GREEN CROP

Wheat rust, particularly Pst, survives and is perpetuated throughout the year in certain areas of the CWANA region. Variation in the crop growth period, availability of different species of *Triticum*, volunteer plants, and collateral hosts such as barley, ensure the presence of Pst year round. Such a wide choice of green bridge is quite unique to Central and West Asia. Hence, in the mountainous regions, Pst survives right within the field all year round, and erupts as an epidemic when favorable weather re-occurs. In places where the green bridge freely occurs, Pst is endodemic. At locations where spring wheat is sown during October/November, Pst is exodemic and arrives each wheat season from survival spots close by. This continuous availability of a susceptible host promotes the rapid evolution of new matching virulence. The seeds that fall at harvest time make the green bridge with the resgenes. This vulnerable stage of Pst surviving on the green bridge can be seized as an opportunity for an effective IPM intervention.

Probably, there are two important Pst epicenters in the CWANA region where the pathogen can be perpetuated on the green bridge year round. These epicenters provide within a short distance various elevation differences which influence both the climate and the duration of the wheat growing season. Narrow, lush, green valleys generate katabatic winds during cool days which push the Pst urediniospores in to the plains and the foothills. Such ideal conditions promote a wide range of virulence and the evolution of new pathogenic forms. Special attention has to be given to these areas to disrupt the green bridge by adopting IPM and by popularizing several improved varieties at the high altitudes. A separate cold tolerant winter wheat program for the hilly areas of CWANA is felt to be a requirement for reducing vulnerability to Pst.

The Caucasus and Kyrgyzstan mountain systems effectively serve as two major epicenters of Pst in the CWANA region.

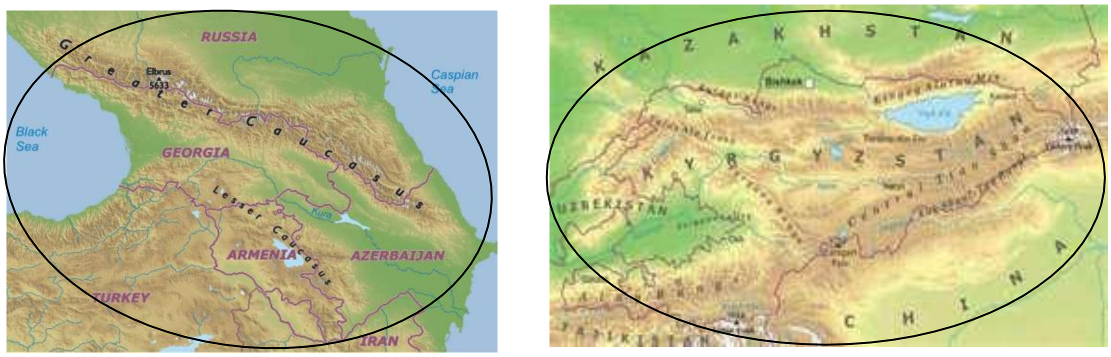


*Figure 4.1. Maps of the Pst epicenter regions in the Caucasus and Kyrgyz mountains*

### 4.1 Summer plowing in the winter wheat areas.

Summer fallowing has been commonly practiced in wheat-based rotation systems in the drylands of Central Asia. This practice helps store soil moisture, check weeds, and promote mineralization. In the hilly tracts of the CWANA, following harvest of winter/facultative wheat in July, summer plowing is necessary to remove the ratoon and volunteer plants. Appropriate farm machinery should be identified for plowing in the self-sown wheat and the ratoon plants. Summer plowing, coupled with a weedicide application, may substantially curtail the green bridge and the extent of over-summering inoculum. Experiments need to be conducted to assess the benefits of disrupting the volunteer plants on the build-up to a Pst epidemic. A practical and robust IPM program to control Pst can be developed.

### 4.2 Sanitation

Disposal of winter wheat straw, rather than piling it on the farm, may contribute towards a reduction of the over-summering inoculum. Ripe, but not yet dried, straw and ratoon wheat plants help in early disease establishment. Grasses, wild *Triticum* sp., roadside spilled-seed volunteers, and their roles as green bridges need to be quantified in order to recommend crop sanitation strategies.

### 4.3 Seed treatment with systemic fungicides

Several formulations of systemic fungicides are available for seed dressings which will protect the plant from Pst for 60 days after germination. An IPM package, involving summer plowing, pre-sowing weed control, growing a moderately resistant winter wheat variety, and seed treated with systemic fungicide can be designed to minimize crop loss from Pst. Identifying a proper spreader, wetter, the correct formulation of the systemic fungicide used as a spray, and organizing a fungicide resistance management community is recommended. A fire-fighting strategy to check the Pst epidemic is to be developed and validated for use when an 'Operation Save the Crop' exercise becomes necessary.

### 4.4 Initial focus containment technology

Once a farmer or the roving survey team identifies an early infection focus of Pst then some pre-emptive actions must be taken immediately by the community of farmers. This may amount to a large-scale, ultra-low volume fungicide spray operation using the appropriate machines. A set of new field experiments on chemicals, their formulations, adjuvants, spreaders, and delivery systems having a minimum impact on the ecosphere need to be designed. Having the chemical input industry join the consortium to address these issues is one possible option.

### 4.5 Varietal design/mosaic

The CWANA has 50 million ha under wheat and the epidemiological zones identified provide exciting opportunities for applying modern concepts of disease management. Creating a varietal mosaic with differing ideotypes and resgenes is another tool in the IPM package. Simulating the spatial and temporal spread of Pst in the context of the varietal mosaic will throw light on the number of varieties needed to call it diverse, the area that it can occupy, etc. Since the topography is rugged and the length of the wheat growing season varies, a blend of maturity types and varietal mosaics can be examined as a Pst management strategy. Central Asia alone has 15 million ha under wheat and so offers great scope for innovating new disease management strategies. Turkey and Iran are other areas where varietal mosaic, gene deployment, and other host resistance strategies can be applied. The leverage provided by winter wheat, facultative wheat, and spring wheat for gene deployment can be used to disconnect the Pst epidemic potential.

### 4.6 Planned deployment of resgenes over space and time

Very closely linked markers are available for several Yr genes and have been validated for application in active plant breeding programs. Field and seedling based reactions suggest that the following Yr genes accord resistance in different epidemiological zones. This differential response is to the advantage of gene deployment and can be exploited under the new initiative. The effectiveness of Yr genes varies in epidemiological zones 2, 3, and 4.

*Table 4.1. Effective Yr genes in epidemiological zones 2, 3, and 4*

| Country | Genes that are effective |
|---|---|
| Iran | Yr1, Yr3, Yr4, Yr5, Yr8, Yr10, Yr15, Yr18, YrSD, YrND, Yr SP, Yr SK, and Yr SU |
| Pakistan | Yr1, Yr4, Yr5, Yr8+, Yr10, Yr15, Yr17, Yr SP, and Yr CV |
| Kyrgyzstan | Yr2+, Yr4+, Yr5, Yr10, and Yr15 |

A more critical study should be made using the relevant Pst pathotype to characterize the known Yr genes at the seedling and adult plant stages. The stability of resgene expression is important and needs to be documented accurately. Having done that, locating these resgenes on the chromosome and adopting a procedure to rapidly introgress the gene can be worked out. Gene deployment between and within the zones can be examined as a new opportunity for associating the NARS and advanced laboratories with the new initiative.

## 5. GERMPLASM DEVELOPMENT AND SHARING

The international institutes and the NARS hold most of the world wheat collections, and much is yet to be characterized for various traits. Characterization needs the time of the experts to phenotype the material under field and under controlled conditions. This expensive exercise will generate a tremendous amount of data and, by using appropriate computing facilities, molecular biologists can gather new insights on the expression of several genes. Phenotyping the core germplasm that has evolved in the

CWANA will reveal new knowledge and products for a continuing plant breeding industry. A well-charted action plan to churn the elite or core wheat germplasm for new traits is felt to be an urgent requirement to contain Pst.

### 5.1 Resource crunched NARS

Historically the international crop research institutes have been the benefactors of advanced lines and material suitable for release as varieties to most of the NARS in the region. The NARS became over dependent on the easy availability of ready to release material, since it saved them from drudgery and the need to be responsive to their national farming issues. The research and development investment in these countries is just 0.2% of their gross domestic product. Under such a situation, the various international trials and nurseries are the lifelines for their crop improvement programs. This over-dependence on international material is evident from the release of several Attila, Kauz, and bio-similars by the different countries of the region. The inadvertently created pan-genetic vulnerability to Pst became a matter of great concern. Involvement of the NARS in addressing the Pst problem is necessary and the new initiative, at best, can only catalyze the process of change.

### 5.2 Central-NARS shared crossing block for CWANA

In the major epidemiological zones of CWANA, where expression of wheat is better (bread wheat, durum, *dicoccum*, spring, facultative, and winter wheat, and barley), an International Cooperative Wheat (and Barley) Crossing Block can be planted as a common facility. The NARS staff can get their 'felt-need' crosses done, aided by the cooperative program, and advance the generation, after selection, under their respective national programs. This central crossing block will provide better and greater access to elite germplasm. Many countries in the CWANA region have difficulty in documenting their germplasm, making a core collection, and designing an effective crossing block. The expertise and talent of the CGIAR institutes can be extended to run the cooperative program and train several young scientists in plant breeding.

It is felt that the NARS should shoulder a little more of the burden of variety development and, by so doing, develop grass-roots level variety diversification. Various blends and models of the centrally shared crossing block can be developed. Parental lines, plant breeding procedures, and selection approaches should be varied deliberately between the major zones to create grass-roots level variety diversity. Ultimately, CWANA will have a sustainable wheat production and improvement program which will fully restrict the outbreak of Pst epidemics. The up-coming scientists trained in the new initiative will be able to man their future crop improvement establishments.

### 5.3. Supply of various types of nurseries to NARS and others

Most of the International wheat and barley nurseries are well stocked with broad-based material generated through cross combinations. Also the proportion of limited backcross lines and sister lines in the internationally supplied nurseries are on the increase. Since the International Maize and Wheat Improvement Center (CIMMYT) wheat nurseries are geared to supplying to large mega-environments, their outputs are not really appropriate for the CWANA region which has contrasting growing conditions.

Plant breeders from the CWANA region should be motivated to visit the International Institutes and select the lines that they consider will fit well in their conditions. The supply of elite material, synthetic bread wheats, and lines with traits unique to the CWANA region will stimulate the NARS to take up nation-specific crosses from which to breed better varieties. The NARS of the region should develop a culture of sharing/exchanging their field data and selection history with the international wheat selection and performance data base. This two way flow of information will make variety development efforts a pleasure rather than being a chore.

## 5.4 More focus on durum and barley is advocated

The dominance of Attila, Kauz, and bio-similars in the area came about when bread wheat replaced durum and barley. This narrowing of the cultivation of crop species to bread wheat created a monoculture, increased the spatial and temporal uniformity of bread wheat, and thus enabled Pst epidemics to occur. The region prefers durum and barley as their principal cereal food and so a super program to improve durum and barley in the CWANA is advocated. The involvement of institutions from outside the region will be beneficial and facilitate a catch-up with progress made elsewhere in the world. Also incorporating new Yr genes from other tetraploid wheat in to durum would broaden the resistance base. Local barley is widely cultivated still and preferred as the area's fodder-cum-grain type. Efforts to diversify the Yr genes in barley will add to the Pst epidemic management strategy.

## 5.5 Widening the resgene base

To widen the genetic base, multicenter shuttle breeding can be considered as an option. Testing the segregants within the first few generations in widely separated locations within the region (such as the low elevations and high elevations in Turkey or in Iran) can result in the development of lines with a broader resistance to Pst virulences than are currently present in the region. This micro-shuttle breeding as an inter-country cooperative program can be carried out with the objective of breeding wheat with differing resgene combinations. By planting a variety with varying resgenes along the Pst dispersal path, a gene deployment strategy can be institutionalized. Constantly evolving Pst virulence in the epicenters indicates that there may be several resgenes in the native wheat of this area. The West Asian and Caucasian collections may provide an exciting opportunity for an international project on resgene discovery.

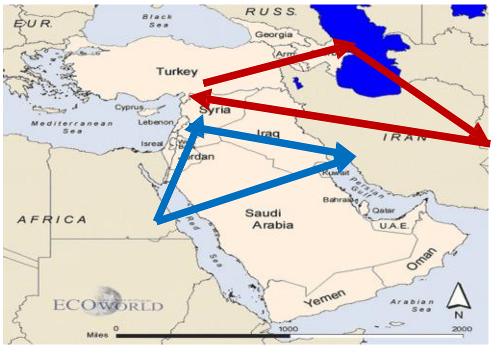


*Figure 5.1. Within zone shuttle breeding of winter wheat (red arrows) and spring wheat (blue arrows)*

## 5.6 Making targeted crosses for breaking pan-genetic vulnerability

As discussed earlier, several Yr genes are able to accord resistance to Pst under field tests against Yr9 + Yr27 virulences. These genes can be incorporated in advanced lines in various permutations and combinations. Since there are many Yr genes which have been reported to give total resistance against all prevalent virulences of Pst in the CWANA region, a mutually agreed gene deployment program can be designed, and executed. A high degree of regional cooperation, backed by an efficient surveillance and virulence typing program, will be required to implement this strategy.

## 5.7 Breeding winter wheat varieties for high altitudes in the CWANA region

In the West Asia, Caucasus, and south Central Asia area of the CWANA region (Kyrgyzstan and the adjoining hilly tracts), around 16.5 million ha is under winter and facultative wheat. Winter wheat is sown by September and the crop matures in July. The Pst survives in a sporulating form on the freely available green bridges that are genetically identical to the just harvested wheat crop. The pathogen being an endodemic disease, the severity builds-up quickly and varietal resistance is overcome rapidly. Varieties such as Bezostaya1 and Sultan 95 dominate the acreage even though they have outlived their usefulness and are now susceptible to Pst. The International Winter Wheat Yield Trial (IWWYT) and other nurseries meant for winter wheat growing areas produce varying results as a consequence of the differences in climate at the test locations. In the IWWYT there are several lines which are superior in yield at some specific sites. But their rating across locations is poor and so the material is rejected. Hence specifying a separate winter wheat nursery for each epidemiological zone is recommended.


*Figure 5.2. Areas of West Asia (enclosed by black line) demanding good winter wheat, having very high mountains, and where Scandinavian type winter weather prevails*

In the CWANA region, the winter wheat breeding program is not well organized and the elite material is made available through the International Winter Wheat Improvement Program (IWWIP). The outstanding materials from the IWWIP get picked-up by the Central Asian republics for release in their countries. Under the new initiative a separate winter wheat breeding program (bread wheat and durum) is recommended exclusively for the CWANA area. The winter wheat improvement in Turkey needs strengthening as the current efforts have not made any substantial contribution to Pst management. Hence, a few more active winter wheat breeding programs are recommended for the CWANA region. The region's needs are diverse – cold tolerant, scab, and rust resistant wheat varieties with good grain quality. As there is a substantial area under winter wheat in these resource and technology poor countries, they need a strong cooperative winter wheat improvement program. This can be provided under this new initiative. The winter wheat program may not necessarily incorporate the same genes that the spring wheat breeder program uses. Deploying different combinations of resgenes in winter and spring wheat will enable gene deployment and avert severe infestations of Pst.

A thorough discussion with stake-holders to identify problems and set priorities needs immediate attention. The information available indicates that a poor seed replacement ratio for winter wheat has been happening following formation of the independent Central Asian republics. The supply of the superior winter wheat varieties Krasnodar from the Soviet Union has been reduced considerably and this has resulted in no new winter wheat varieties being released. This is also one reason why the spring wheat area in the region has increased in the last decade. This dilution of plant breeding efforts focused on winter wheat has cost the CWANA nations substantially by way of increased vulnerability to Pst.

## 5.8 Pyramiding or staking resgenes for specific zones

Most of the modern day wheat varieties carry more than one Yr gene and thus withstand yellow rust infection. But the evolution of new aggressive virulences of Pst has breached the resistance gene barrier. One way to overcome this crisis is to pack a greater variety of Yr genes – preferably like Yr3, Yr4, Yr5, or Yr15 – along with adult plant resistance genes, like Yr18. Gene Yr17 is lined with Lr37 and Sr38 and the expression of resistance against yellow rust is significantly influenced by the background in which the gene is present. Similarly Yr16 is involved in durable resistance to Pst in Cappelle-Desprez. This useful gene gave that variety a very long field life. It is recommended that this useful Yr gene be combined with other major Yr genes. Such pyramiding of both types of resistance genes is strongly recommended. Development of reliable multiple markers will be useful in accelerating the incorporation of these genes in a variety of backgrounds. Sometimes pyramided genes may lead to gene complementation, enhancing the spectrum of resistance compared to either of them alone. Therefore, systematic pyramiding of resgenes can result in the development of good genetic stocks for subsequent use in various crossing programs.

Isolates of Pst virulent on Yr5 are extremely rare and so Yr5 is an excellent candidate in breeding for stripe rust resistance. Because Yr5 resistance is race specific, the gene should be used in combination with other effective genes and/or with an adult plant resistance gene. Now several useful markers have been made available to plant breeders for a reliable disease resistance breeding program.

# 6. PRE-BREEDING, BIOTECHNOLOGY, AND GENETIC RESOURCES

In order to quickly replace Attila, Kauz, and bio-similars, it is necessary to embark on a rapid plant breeding program. There are several ways of doing it and blending them, as per the target objective, would be the most appropriate. By growing multiple generations in a calendar year, it is possible to advance the segregating population to a uniform state in a much shorter time span than by conventional plant breeding methods.

## 6.1 Gene discovery

Discovering new rust resistance genes should be promoted to ensure a supply line of Yr genes for the plant breeders to blend them in various varietal backgrounds. Compared to the other two rusts of wheat, relatively less has been reported and characterized on resistance genes against yellow rust. This suggests that there is considerable scope for identifying new Yr genes either through genetic studies or through molecular approaches. Through map-based cloning, gene Yr36 (WKS1) has been discovered. This is a gene which confers resistance to a broad spectrum of Pst virulences at relatively high temperatures (25 to 35°C). Gene expression studies reveal that transcription encoding of the complete protein was upwardly regulated at high temperatures. This gene includes a kinase and a putative START lipid-binding domain. Five independent mutations and transgenic complementations have confirmed that both domains are necessary to confer resistance. Gene Yr36, from a race of wild wheat, has been transferred to a handful of domesticated pasta and bread wheat varieties. That wild wheat was collected from Israel, where the farmers have been growing wheat for centuries. Discovering such useful APR genes and deploying them in variety development will be strengthened under the new initiative. Because of climate change it is advocated that the Yr36 be integrated with other Yr genes.

There are dual APR genes which operate against more than one rust disease of wheat. They invariably occur together, such as Lr34/Yr18, Lr46/Yr29, etc. The Sr9 locus has multiple alleles designated as Sr9a to Sr9g. Gene Yr18 has been shown to be truncated and present in several forms in different lines designated Yr18a to Yr18f. This also calls for caution regarding which allele of Yr18 is the one selected. Attila and bio-similars carry Lr46/Yr29 and expression varies with the temperature and background of the material.

To diversify stripe rust resistant resources, wheat breeding stocks developed from synthetic wheat can be considered. Recently the Chinese have discovered a new yellow rust resistance gene in a CIMMYT supplied synthetic line CI110. There appears to be a great opportunity to examine the elite synthetic lines and derivatives of wide crosses while searching for new resgenes. If such genes can be put into the public domain then several NARS will be able to blend them and breed varieties to resist Pst. Unfortunately the private seed industry gene discoveries carry a price tag and access to those products is difficult and cumbersome. Without getting into 'Omics' studies that are capital and instrumentation intense, the new initiative should examine the option of discovering new Yr genes and placing them in the public domain. A consortium of institutions, involving those of repute from the CWANA region, could develop suitable programs for this purpose under the new initiative.

There are probably several more resistance genes in the native *Ae. sharonensis* (Sharon grass) and *Hordium vulgare* accessions of the fertile crescent and West Asia, North Africa, and Caucasus regions awaiting discovery. The new initiative should take stock of what has been achieved and which other novel gene needs characterization for suitable use in the on-going molecular plant breeding efforts.

## 6.2 A re-look at old land races/improved tall for new resgenes

Several wheat lines and cultivar from the southwestern region of China have been resistant to Pst. In the variety Chuan-nong 19 a new Yr gene (YrCN19) has been identified using microsatellite markers. This Yr gene has shown potential in marker assisted breeding of wheat. Chinese researchers have also shown that a native improved tall Indian wheat line, C591, has a novel Yr gene. In a Taichung 29 x C591 cross a single dominant gene was identified and has been temporarily designated as YrC591. The SSR markers mapped the resistance gene on chromosome 7BL. In seedling tests with five Pst races, the reaction patterns of C591 differed from those lines carrying Yr2 or Yr6, which are also located on chromosome 7B. This led them to conclude that, probably, C591 carries a new Yr gene designated as YrC591. This novel yellow rust resistance gene can be pyramided with other useful resistance genes. The competitive window provision in the new initiative can be used to fund research to identify new Yr genes and for using these genes in active plant breeding programs.

## 6.3 Development of reliable markers for molecular plant breeding

There is a paucity of reliable markers for various Yr genes. To accelerate the process of incorporating multiple yellow rust resistance genes along with other desirable traits, development of reliable molecular markers is necessary. Various molecular markers, such as restriction fragment length polymorphism, random-amplified polymorphic DNA, amplified fragment length polymorphism, and microsatellite markers (ISSR, SSR), have found wide acceptability and use of the technique depends on the amenability of the material. Molecular markers linked to Yr5, Yr10, Yr15, Yr17, Yr26, Yr28, Yr29, Yr34, YrH52, and Yrns-B1 have been reported. Development of a map of the resistance gene, using flanking markers and multiple markers for a given gene may enhance the fidelity of the selection made. Development of microsatellite markers offers great promise as they have been found to be more functional in wheat. By establishing a marker repository for the CWANA, validating the utility of these acclaimed markers for material used in the region will facilitate the yellow rust resistance breeding program substantially. Development of new microsatellite markers for the remaining Yr genes and the APR system requires focusing on the dire need to diversify the wheat varieties in the CWANA region.

## 6.4 Double haploid (DH) strategies

Microspore embryogenesis has been standardized by using a chemical inducer to produce large quantities of microspore-derived green plants from a wide spectrum of genotypes under optimal culture conditions. The overall efficiency, in terms of numbers of green plants/single spikes, ranges from 50 to 5500, indicating that the procedure would be effective for use in breeding and research programs. Winter wheat genotypes responded in the same way as spring wheat when they were fully vernalized. The high efficiency and simplicity of the system make DH production practical for biological research and wheat breeding. An efficient DH technology can greatly reduce the time and cost of cultivar development. The Washington State University operates a double haploid facility on an outsourcing payment basis; anyone can hire the facility to develop a DH line. The DH in many cases can serve as inbred and facilitate the development of reliable molecular markers. Use of DH in yellow rust management opens up an exciting opportunity and should no longer be ignored.

## 6.5 Rapid generation advancement

Variety development is a laborious, painstaking, and time consuming activity. It, involves evaluating a large numbers of segregants and picking the correct plant that has the potential to become a variety. Time taken to develop a variety can be shortened by proper planning and applying the current technology. The one that was used by Howard a century ago employed off-season nurseries for generation advancement and for doing negative selection. Creating an appropriate summer nursery facility in the CWANA region will be useful. Vernalized winter wheat seeds can be sown and harvested alongside spring wheat and thus effectively two generations per year can be raised.

The single seed descendant (SSD) permits multiple generations to be raised each year. Then it is possible to advance a population to a genetically stable generation in a much shorter time than conventional plant breeding methods that generally use only one generation per year. The time taken from making a cross to release of a variety can be reduced by approximately two or more years. There is opportunity to select for desirable traits between SSD generations and, ultimately, to select lines with multiple seedling resistant genes, grain type, etc. The disadvantage is that the information on agronomic selection and field suitability of the SSD population may not be there. This limitation can be overcome by a relatively large F6 SSD population that may permit still transgressive lines with agronomic traits. From a cost perspective, the SSD is more economical than DH, but both procedures have advantages. Lines generated through SSD can be produced at less than half the cost of those created through DH.

Timing is one of the most important issues that needs to be considered when a breeder plans to use SSD to its maximum advantage. It is possible to design a program which will cater for either an autumn or spring crossing block and deliver seed grown from either the F4 or F5 depending on the requirements of the individual plant breeder. Under glasshouse conditions in small cup pots, three generations can be completed in a year. In each generation a small ear head with 2 or 3 matured grains is harvested for further generation advancement. Establishing well organized SSD, DH, and summer nursery facilities will add to the efficiency of the plant breeder in developing good genotypes in a short time span.

## 6.6 Shuttle breeding for a wider adaptation

Earlier, a cooperative international wheat and barley crossing block was proposed. At least two generations of segregants from the crosses should be raised at the target environment for which the selection was intended. By doing so, a widely adapted material for cultivation within an epidemiological zone can be developed. Since the countries in Central Asia have coiled international boundaries, variety seepage between countries is inevitable. Therefore, one epidemiological jurisdiction, or a larger comparable tract, is to be the focus of the plant breeding efforts.

Shuttling of the material between zones to screen for rust resistance should be encouraged, as the pathogen spreads freely from one epidemiological zone to another adjacent one. Evaluating the elite material in the adjoining areas will forewarn of the performance of the genotype. This two tier approach, involving the NARS, will promote farm gate level variety diversification directed at curtailing Pst.

## 7. Identification of elite lines and basic seed production by the NARS

### 7.1 Identification of elite lines

ICARDA would hire a very senior and globally well know wheat scientist to work with all the CWANA NARS to identify elite wheat lines for release and basic seed production. These lines would have relevant traits – yield potential, stripe and leaf rust resistance, and septoria tolerance if needed – incorporated into them, along with good quality characteristics. ICARDA believes that this process would enhance the rate of acceptance of YR resistance varieties in the region.

### 7.2 Seed requirements of CWANA

There is substantial area under wheat and barley in the various CWANA countries; this includes areas under winter wheat, facultative wheat, spring wheat, winter durum, spring durum, Khapli wheat, and barley. Seed replacement would be at best 20%, including farmer to farmer seed exchange. If farmers in the CWANA region follow a seeding rate of 100 kg/ha, then 50 million tonne will be required

It is possible to calculate the amounts of nucleus and breeder seed that would be required to produce 50 million tonne of certified seed. Unfortunately the region has a fragile infrastructure and finds it difficult to cope with the demand for quality seed. In addition to a shortage in quantity there is also a quality limitation. Most of the vintage harvesting, seed cleaning, and processing machines used result in a compromise on seed quality standards. The seed purity and quality standards followed in the CWANA region need to be assessed and the gray areas addressed to ensure the entry of new varieties. The CWANA seed chain which is presently followed provides ample scope for professionalism at all levels of the seed production chain.

### 7.3 Seed replacement and variety replacement ratio

The majority of farmers in the CWANA region use seeds saved from the previous season's crop. The seed sown is also more than a year old and this affects the germination and vigor of the seedling. The physical impurities, coupled with old seed, result in a poor crop stand. Physical purity and genetic fidelity are invariably compromised as the national seed law is ineffective. An Food and Agriculture Organization of the United Nations document indicates that the variety concept is almost non-existent despite the availability of the seed of some improved varieties. There is considerable scope for implementing standard seed production procedures and for initiating a seed quality assurance program. The village development committees can be energized to cater to these immediate requirements. Small landholders can be brought under one umbrella to take up seed production practices under technical supervision. If the pattern of seed villages followed in India is copied, seed production can be organized and small seed companies can be accommodated as partners in distributing the product to farmers. Over a period of time these seed traders may become well rooted companies. Under the new initiative, bold and imaginative steps on seed policy advocacy will be encouraged.

## 7.4 Seed industry

An organized seed sector is still in its formative years in most of the countries of the CWANA region. Leadership, capacity building, making material available under some agreement, and a system of business ethics are necessary. If productivity is to increase and Pst resistant varieties are to hold sway, then it is essential to promote regional-based seed companies. The program Director, or CEO, must act as an honest broker in getting venture capital into the seed sector and assisting in the development of this sector on sound principles.

## 7.5 Maintenance breeding (MB) and varietal fidelity

The NARS institutions in the region can be assigned the responsibility of characterizing the wheat variety using international descriptors. The descriptors come in handy in selecting true-to-type plants/ear heads to start the nucleus seed production. The seed purity depends on the rigor of the MB program in avoiding all steps that lead to genetic impurity/shift. A variety from a long crossing and pedigree lineage or lines that gets bulked at F6 may produce some transgressives that look phenotypically distinct or vary in disease resistance. These plants of re-assorted genetic makeup gradually drift/corrode the genetic base of the original variety. Such impure varieties are uneven in look, behave like a mixture, and lose their yield superiority. If MB is done properly or seed replacement made periodically then such a situation can be averted and yield capacity, etc., are not affected. To undertake MB demands a good understanding of genetics, plant breeding, and seed science.

Being a specialized responsibility, the CWANA region scientists and seed technologists need a good orientation in MB; this is essential for a strong seed production system. The NARS institutions in the region need capacity building in many of these specialized areas and this will also stimulate the growth of a seed industry in the region.

## 7.6 Seed laws and quality assurance

Most of the countries in the CWANA region are members of the World Trade Organization and have opted for the International Union for the Protection of New Varieties of Plants (UPOV) system of plant variety protection. The region may have diverse seed laws governing the purity, labeling. and marketing of seed. It is not clear if there are any guidelines on handling crop biotechnology products. It is necessary to have harmony between these laws, including the quarantine procedures and plant health services. Regional advocacy efforts must be initiated for greater germplasm movement, marketing of seed across national boundaries, and in extending intellectual property rights to the owners of the variety product.

## 7.7 Pro-farmer incentive to procure good seed

Contract farming can be one option for large-scale seed multiplication. By supplying seeds and other agri-inputs, quality seed can be produced under supervision of technical personnel. The contract farmer is offered a premium price through a buy back arrangement with the grower. A central monitoring team can visit the seed production plots to check production standards and certify the output. Production of foundation stage seeds and certified seed can be taken up in such a decentralized manner even by state seed corporations.

Keeping in mind the need to periodically replace old cultivars with better varieties, the CWANA regions may establish seed banks at the national level. Storing at 5°C an adequate quantity of breeder seed with low moisture content will make it possible to retain seed variability for five years. Also in the event of a defeated variety creating a crisis, seeds of the resistant variety can be withdrawn from the seed bank, multiplied, and distributed to farmers to replace the susceptible ones. The proposed

initiative should address the seed production system in the CWANA region and make it a profitable proposition.

## 8. CAPACITY BUILDING AND POLICY ADVOCACY

Skill development is likely to be a continuous requirement in the CWANA region and will require substantial talent-developing activities. In almost all aspects of wheat improvement there is a paucity of talented personnel to run programs. It is, therefore, necessary to establish close links between overseas institutions, and the NARS in the CWANA region. Joint degree programs for M.S. or Ph.D. students and post-doctoral training needs should be identified. Technicians, government officials, NGOs, elite farmers, and policy makers can to be sensitized to the need to have a resilient cereal improvement program in the CWANA region.

The following are potential subject areas for consideration under the capacity building heading. The courses would be of varying length and content.

- Skill improvement in survey, surveillance, and artificial epiphytotic conditions
- Patho-typing and gene postulation
- Conducting coordinated trials and evaluation procedures
- Advanced plant breeding techniques
- Fundamentals of molecular plant breeding
- Seed production systems
- Seed processing and branding
- Methods in technology transfer
- Wheat production strategies and connected policy issues
- Crop insurance – orienting government policies to be pro-farmer
- Cropping system innovations and a wheat-based value chain.

Developing course content, training manuals, and getting the right resource personnel, producing printed matter, and audio-visual material all need due attention. Each course should have a budget to cover the expenses of the trainees, resource personnel, material, and other costs. Capacity building is required at various levels for reviving resilient wheat cultivation in the area.

### 8.1 Policy advocacy

For efficient control of Pst and to enhance the productivity of winter cereals it is necessary to advocate policies for various governments in the CWANA region. These policies would be based on sound scientific principles and viable economic options. Policies related to a coordinated approach between the NARS and government can be made easily by the government issuing directives for Pst surveillance and virulence typing at a centralized place. Modifications may be necessary in the plant health and quarantine act to provide official support for such activities. Since the pathogen spreads across national boundaries rather freely, concerted action by all countries in the region is necessary.

There is scope for bringing in additions and modifications to the laws that govern seed production and distribution. Procurement of harvested grain, grain handling, and marketing are other gray areas that need to be addressed. By supporting self-help groups and NGOs in the region, policy advocacy activities can be channeled appropriately. Bringing the CWANA grain trade under world trading procedures would be a welcome move. If surplus wheat for export by Central Asia is suddenly dumped on the international market it will upset the global price of the commodity. Integrating the region with the rest of the world wheat community is very much required as the region accounts for 50 million tonne and a substantial population is dependent on this cereal as their staple food.

## 9. Intersection areas for interaction

A two pronged strategy is required to effectively combat Pst. So far, only the issues that address specific spheres of action or program circles have been discussed. But there are certain activities that cut across the program circles. They represent a common need for all the nations in the region to develop effective management of Pst.

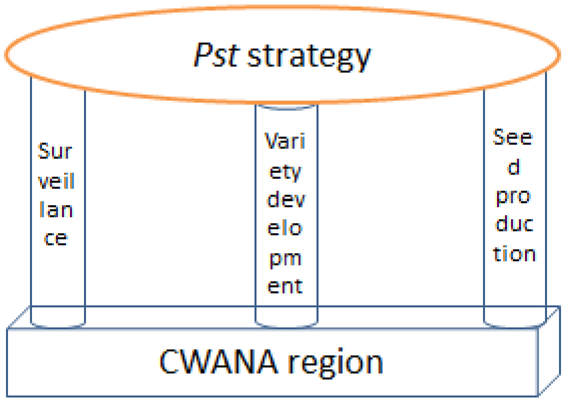


*Figure 9.1. Common pillars of a Pst strategy for CWANA*

### 9.1 Sharing pest surveillance

Surveillance information on Pst, collected from various sources, should be made available to every agency. Samples from infected fields must be identified on the international differentials and the results should be shared between nations. Based on a reaction matrix, resgene postulation, and a blueprint of where various gene combinations will be deployed, the information should be shared with all the concerned nations of the region. On-line information for the entire CWANA region needs to be made available by the coordinating unit so that the NARS can issue location-specific pest warnings and decide if any prophylactic action is necessary. An on-line newsletter, issued fortnightly and based on crop, weather, and disease surveillance, can be designed as a cross-cutting program. The secretariat and professionals attached to the program should be conversant with the cropping practices of the region, should coordinate between the NARS and the government functionaries, and ensure that crop health never becomes a matter of concern.

### 9.2 Cooperative varietal development

The CWANA region can be aggregated into three mega zones, such as the Morocco belt, Central, and West Asia. The Indian sub-continent, and Ethiopia are peripheral countries and do not constitute the core of our concern. For each of these zones, annual wheat workshops can be planned with a focus on conducting yield trials, exchanging germplasm, designing crossing blocks, shuttle breeding, and various plant pathological and agronomic activities. Developing a common vision and goal to be achieved should be the motivating force behind this exercise.

### 9.3 Seed production

Quick variety replacement, creating a varietal mosaic, and deploying resgenes over space and time will be the backbone of a yellow rust management strategy for the CWANA region. At any given time, a large number of varieties should be in the seed production chain and meeting the seed deficit between the needs of the nations being coordinated. Keeping the seed production chain efficient would demand greater coordination and interaction with all programs. The farmer field demonstrations, seed village promotion activities, and attending to the needs of barley growers would constitute the third cross-cutting activity

The CEO should be able to coordinate and steer the whole program in such a manner that productivity gains are sustained and losses from wheat diseases, particularly Pst, minimized.

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# About ICARDA and the CGIAR

ICARDA

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is one of 15 centers supported by the CGIAR. ICARDA's mission is to contribute to the improvement of livelihoods of the resource-poor in dry areas by enhancing food security and alleviating poverty through research and partnerships to achieve sustainable increases in agricultural productivity and income, while ensuring the efficient and more equitable use and conservation of natural resources.

ICARDA has a global mandate for the improvement of barley, lentil and faba bean, and serves the non-tropical dry areas for the improvement of on-farm water use efficiency, rangeland and small-ruminant production. In the Central and West Asia and North Africa (CWANA) region, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming systems. It also works on improved land management, diversification of production systems, and value-added crop and livestock products. Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.

CGIAR

The Consultative Group on International Agricultural Research (CGIAR) is a strategic alliance of countries, international and regional organizations, and private foundations supporting 15 international agricultural Centers that work with national agricultural research systems and civil society organizations including the private sector. The alliance mobilizes agricultural science to reduce poverty, foster human well being, promote agricultural growth and protect the environment. The CGIAR generates global public goods that are available to all.

The World Bank, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), and the International Fund for Agricultural Development (IFAD) are cosponsors of the CGIAR. The World Bank provides the CGIAR with a System Office in Washington, DC. A Science Council, with its Secretariat at FAO in Rome, assists the System in the development of its research program.