Integrated Gene Management: Conservation, Improvement, and Sustainable use of Agrobiodiversity in Dry Areas (MegaProject 2)

Introduction

The Integrated Gene Management (IGM) MegaProject was restructured to show how ICARDA delivers key products to meet the needs of the poor and marginalized farmers in the developing world. It is a client-focused project with achievable targets that will have impact. The project addresses food security needs of the dry areas and CWANA region in particular with a major focus on improving water productivity of ICARDA's mandate crops through breeding drought tolerant, high-yielding and better quality varieties, better farming practices and human resource development. The project activities are implemented in partnership with national and non-governmental research-for-development institutions to deliver products and services which have both global and regional importance. The flagship products for the period under review (2000-2005) include: 1) drought tolerant varieties of wheat, barley, chickpea, lentil, faba bean and feed legumes; 2) improved methods and/or tools for genetic enhancement, e.g. molecular markers and participatory plant breeding; 3) biofortified cultivars of barley and lentil; 4) expanded knowledge on *in situ* and *ex situ* conservation of accessions of cereals and legumes through molecular finger-printing and targeted field evaluations of economic traits; 5) strengthened capacity of national partners; and 6) meeting seed demand in war-affected countries.

The recommendations of the 4th EPMR on genetic improvement of ICARDA's mandate crops were implemented by the Germplasm Program (a predecessor of IGMMP). In 2004, the program was highly rated by a Center Commissioned External Review (CCER). The activities of the project were subsequently revised to cater to the CCER recommendations. This report summarizes the main achievements, current activities, and future plans of the project under the following headings: 1) Genetic Resources Conservation, 2) Germplasm Improvement of Barley, 3) Germplasm Improvement of Wheat, 4) Germplasm Improvement of Food Legumes, 5) Germplasm Improvement of Feed Legumes, 6) Integrated Pest Management, 7) Biotechnology, 8) International Crop Information System, and 9) Human Resource Development.

As background to the wheat improvement work, from 1996 to 2003, there was a joint CIMMYT/ICARDA wheat improvement program for WANA (later expanded to CWANA), based at ICARDA, with breeders of spring bread wheat and durum wheat posted by CIMMYT to ICARDA headquarters, and a joint program on facultative and winter wheat in Turkey with major Turkish cooperation. The CIMMYT wheat breeders at ICARDA were withdrawn in 2003 and then re-hired by ICARDA. From 2003 to 2005 the cooperation with CIMMYT in wheat improvement was confined to the facultative and winter wheat program in/with Turkey. In December 2005 ICARDA and CIMMYT agreed to a joint ICARDA-CIMMYT Wheat Improvement Program in CWANA hosted at ICARDA and run by a jointly appointed Director.

Genetic Resources Conservation, Evaluation, and Utilization of Cereals and Legumes

Introduction

The goal of the Genetic Resource Unit (GRU) is to enhance food security and sustainability of agricultural production systems based on the conservation and utilization of the biodiversity of ICARDA's mandate crops: wheat, barley, lentil, chickpea, faba bean and pasture and forage legume species and their associated rhizobia. Saving and investigating the biodiversity still available in the CWANA, the center of origin and diversity of the world's major food crops, is not only important to meet the present challenges, but is indispensable for future needs of agriculture. The biodiversity "assets" represent key sources of resistance to biotic and abiotic stresses and are indispensable for future crop improvement and food security in developing countries and low-input farming systems, in particular.

Achievements

- Germplasm collection: A total of 3,728 new germplasm accessions were collected from 24 collection missions in 11 countries (Armenia, Azerbaijan, Georgia, Jordan, Kazakhstan, Kyrgyzstan, Lebanon, Romania, Syria, Tajikistan and Turkmenistan) in collaboration with NARS and other partners.
- Germplasm acquisition: In addition to the collections made by GRU, an additional 11,087 new accessions were obtained from other sources, bringing the total newly acquired accessions under the period under review to 14,815.
- Germplasm *ex situ* conservation: About 106,000 accessions were FAO designated with nearly 133,000 accessions in the active collection and 100,000 accessions in the base collection. Direct and indirect (via the germplasm donor) safety duplication now covers 118,047 accessions, i.e. 90% of all GRU holdings.
- Germplasm documentation: All genetic resources activities and operations were fully computerized. Databases were made accessible worldwide via internet through the System-wide Information Network on Genetic Resources (SINGER). A Global Inventory of Barley Genetic Resources including more than 191,000 accessions conserved in 61 major genebanks worldwide was developed with support from the System-wide Genetic Resources Program (SGRP). The Global Database of wheat wild relatives was upgraded and updated and now it contains a total of 19,000 accessions held at 44 genebanks.

- Germplasm distribution: A total of 220,000 seed samples were distributed. Of these 50,000 were distributed to users at ICARDA and 84,000 were dispatched to users worldwide. The rate of distribution of genetic resources samples from GRU is higher than in any other CGIAR genebank.
- *In situ* conservation: GRU coordinated and provided technical backstopping for the US$ 8 million GEF/UNDP funded project on 'Agro-biodiversity conservation and management in the Near East' implemented in Jordan, Lebanon, the Palestinian Authority and Syria from 1999 to 2005. The project promoted *in situ* and on-farm conservation of agro-biodiversity and human resources development. An international conference was held at the ICARDA headquarters in April 2005 to discuss the project results and lessons learnt.
- Pre-breeding: Synthetic hexaploid wheat (6x = 42 chromosomes) was produced through amphiploidization of sterile triploid hybrids between locally adapted durum wheat cv. 'Haurani' and two *Aegilops tauschii* accessions originating from low-rainfall sites (160 and 300 mm) in northern Syria. Natural epidemics of yellow rust and leaf rust and testing in diseases nurseries with artificial inoculation revealed the presence of new resistance genes in materials derived from crosses between wild wheat relatives (*Triticum urartu, T. beoticum, Ae. speltoides)* and *T. dicoccoides*. Sunn pest and Russian wheat aphid resistance was also found in crosses with wheat wild relatives. Some lines gave higher yield under drought stress than the durum or bread wheat parents.
- Training: A total of 353 NARS participants from 24 countries were trained in genetic resources and seed health
- Seed health: Approximately 150,000 in-coming and/or out-going seed samples were tested for seed-borne pathogens.

Current Activities

- Missions in Central Asia and Caucasus countries and other "hot spots" to collect germplasm to fill the geographical or ecological gaps in ICARDA's collections.
- Collaboration with the Vavilov Institute (VIR) in Russia to acquire and/or rescue the unique germplasm of ICARDA mandate crops held at VIR.
- Seed multiplication of newly introduced accessions and accessions with insufficient seed.
- Germplasm characterization and evaluation for agro-morphological descriptors, and generation of new eco-geographical data-sets using GIS for geo-referenced wild species and landrace accessions.
- Molecular characterization and finger-printing of 3000 barley, 1000 lentil and 1000 faba bean accessions in collaboration with the Generation Challenge Program, and a set of 4000 chickpea accessions in collaboration with ICRISAT.
- Germplasm *ex situ* conservation via storing safety duplicates of FAO designated accessions and duplicates of other CGIAR centres, e.g. ICRISAT and CIMMYT safety duplicates.
- Germplasm documentation through linking the GRU databases with GIS, development of a computerized system for molecular data processing, storage and manage-

ment, and preparation of the documentation system for on-line direct access through IVDN/Internet.
- Other activities include capacity building in plant taxonomy for enhancing *in situ* conservation of genetic resources, wheat pre-breeding in collaboration with plant breeders, capacity building of NARS staff in genetic resources through short-term group and/or individual training courses, and introduction of new seed health diagnostic techniques in collaboration with advanced institutions.

Future Plans
- Explore the extensive genetic information databases through the use of the advanced information technology.
- Use molecular tools for germplasm characterization in collaboration with the Generation Challenge Program. Integration of genetic resources activities with other activities in the project.
- Increase support for *ex situ* conservation activities through collaboration with Crop Diversity Trust.
- Strengthen *in-situ*/on-farm germplasm conservation and management of rangeland and arid land biodiversity in collaboration with NARS.
- Develop computerized national genetic resources information systems in the CAC countries and link it with a regional genetic resources information network.
- Strengthen the linkages with the VIR and Australia to rescue the unique VIR collections, and continue wheat pre-breeding in collaboration with plant breeders.

Barley Improvement

Introduction
Barley is grown annually on 56 million hectares globally. Barley grain is used as animal feed, malt and human food. Barley straw is used as animal feed and bedding and as cover material for hut roofs. After combine harvesting, barley stubbles are grazed in many developing countries. Malt is the second largest use of barley, and malting barley is grown as a cash crop in a number of developing countries (see recent review following recommendations of the 4th EPMR). In the highlands of Tibet, Nepal, Ethiopia, Eritrea, Yemen, Andean countries, North Africa, Iran, Afghanistan, India and Russia, barley is used as human food either for bread making (usually mixed with bread wheat flour) or for traditional recipes. The barley improvement project aims at a sustainable increase in barley productivity by adapting the crop to the different farming systems and uses in developing countries with special emphasis in those areas where the crop is grown by resource-poor farmers, thus contributing to alleviation of poverty. To achieve its objective, the project has adopted a strategy based on selection for specific adaptation in space and wide adaptation in time, and has developed an approach to germplasm enhancement based on decentralized selection the target environment, with farmers' participation. To fulfill the global mandate for the improvement of barley, ICARDA has a barley breeder posted in CIMMYT-Mexico to address the needs of Central and Latin

America and 30% of a breeder posted in Tashkent to address the needs of Central Asia and Caucasus countries.

Achievements

- Twenty-five new barley varieties were released in twelve countries; two spring barley lines were proposed for release in Kazakhstan; seven winter barley lines were proposed for release in Kazakhstan, Kyrgyzstan, Uzbekistan, and Tajikistan.
- Drought-resistant barley lines derived from crosses with the wild progenitor *Hordeum spontaneum* were identified and disseminated to farmers.
- Sources of resistance to major pests and diseases limiting barley production were identified, assembled as gene pools and made available to NARS in collaboration with pathologist, entomologists, virologists and NARS scientists. These include sources of resistance to scald, barley stripe, loose and covered smut, barley yellow dwarf virus (BYDV), Russian wheat aphid (RWA), and barley stem gall midge (BSGM). New sources of resistance to BYDV (other than from Yd2 gene) were identified in Ethiopian landraces held at the Vavilov Institute and ICARDA.
- Resistance to BYDV and RWA was transferred to genetic backgrounds adapted to North Africa, and the resistant lines were distributed to NARS; and resistance to RWA was transferred to Ethiopian landraces.
- New sources of tolerance to cereal cyst nematodes (CCN) were identified in Syria and Australia; ‘Tadmor’, ‘Zanbaka’, *H. spontaneum* and other landraces showed the best level of tolerance.
- Decentralized breeding started in both Central Asia and the Caucasus (CAC) and is underway in Latin America. Locally adapted landraces from Latin America have been extensively used in targeted crosses designed with colleagues in the NARS, and segregating populations distributed.

- The project had a leading role in developing and promoting participatory breeding programs in several countries: Syria, Jordan, Egypt, Eritrea, Morocco, and Algeria. One project publication on participatory barley breeding received the CGIAR Chairman’s Science Award at ICW2000 for Best Scientific Paper. A World Bank Mission defined the participatory barley breeding project in the Matrouh Resource Management Project in Egypt “an excellent first example of full participatory adaptive research”. The Challenge Program for Water and Food review panel stated that “this approach is what the CP has been seeking. The new way of doing business.”
- Institutionalization and scaling up of participatory breeding started in Syria by transferring the program currently conducted by ICARDA to the Ministry of Agriculture and Agrarian Reform of the Syrian Arab Republic, and by expanding the approach to other provinces, to other crops (wheat, lentil, chickpea and cumin) and to a larger group of farmers. In Jordan participatory research was institutionalized at the National Center for Agricultural Research and Transfer of Technology (NCARTT) and extended to wheat and chickpea.
- Village-based seed production started in six villages in Syria with the distribution of locally made seed cleaners (links with Seed Unit in MP6).

- In Syria farmers selected and named eleven varieties that were under farmers' large-scale testing; in Egypt five varieties were named by farmers and multiplied.
- Collaboration with the El Shark Company (Syrian brewery) started with the objective of identifying barley lines with good malting profile. One promising line was identified and grown under contract by a number of farmers.
- An International Workshop on "Food barley improvement", organized by ICARDA, FAO, and IRESA, and with the financial support of the OPEC Fund, was held in Tunisia and was attended by more than 30 participants from 13 countries. During the workshop some of the major quality characteristics for barley as human food were identified. The proceedings of the workshop were recently published.
- A Consultative Workshop on Participatory Plant Breeding (CONPAB) was held in Aleppo in 2005 in collaboration between the Mediterranean Agronomic Institute of Zaragoza (CIHEAM) with the objectives of promoting participatory plant breeding in crops that have strategic importance for the drought-prone areas of the Mediterranean region.
- Molecular breeding methods and/or tools were developed. The use of doubled-haploid techniques (anther- and isolated microspore culture systems) for the development of mapping populations was increased. One DH population was developed for the trait 'osmotic adjustment'; new populations are under development for grain content of iron and zinc. Linkage maps to identify quantitative trait loci (QTLs) associated with performances under stress conditions and with straw quality were developed in collaboration with Risoe National Laboratories in Denmark and the Cooperative Research Center for Molecular Plant Breeding in Adelaide, Australia. Marker assisted selection (MAS) was conducted for resistance to Barley Yellow Dwarf Virus in F_2 populations. AFLP markers linked to the Mlg locus controlling resistance to Powdery Mildew were identified and mapped on chromosome 4H. The identified markers will be converted to sequence-tagged site (STS) markers, to be used for marker-assisted selection. Sequencing facilities were established at ICARDA and are now operational.
- QTLs for chlorophyll content and chlorophyll fluorescence parameters were identified under well-watered and drought stress conditions in the population of *H. spontaneum* 41-1 x Arta. No common QTL was detected except one for chlorophyll content, which was identified in both growth conditions. If validated, the results indicate that chlorophyll fluorescence parameters could be used as selection criteria.
- Dissemination: More than one hundred reports, manuals, refereed journal and newsletter articles were published and/or presented at International Conferences, and regional meetings.
- Capacity building: More than 40 national program scientists were trained on participatory plant breeding (PPB), molecular marker technology, exploitation of GxE interaction in plant breeding and breeding for stress environments, breeding for biotic (diseases, insect, virus) stress resistance, grain quality, data and information management in a breeding program, data analysis of PPB trials using REML, as individual trainees or in courses. Two M.Sc. and two Ph.D. students were trained.

Current Activities

- Identification and use of landraces, wild relatives, and other genetic stocks to broaden the genetic base of the crop and to respond to the increased demand for germplasm adapted to diverse environments and uses.
- Development and distribution of new germplasm with higher and more stable yield, improved end-use and nutritional quality, better biotic and abiotic stress resistance and adaptation to climate change. The abiotic stresses addressed are drought (CP-Generation) salinity (ICBA, CRC-MP), and cold (Iran and CAC); biotic stresses are scald, net and spot blotch, Fusarium head blight and stripe rust (ICARDA/CIMMYT barley program), BYDV, Russian wheat aphid, and barley stem gall midge.
- Research on grain end-use quality, including malting, food uses, and nutritional quality (Iron, Zinc, and Vitamin A).
- Study the genetics of physiological dynamics underlying adaptation of barley to drought (conducted through a project funded by the UE and in collaboration with EU institutions)
- Development of methodologies to enhance the effectiveness and efficiency of germplasm development and dissemination.
- Farmer participatory breeding research continued to expand and includes collaboration with NARS in Egypt, Eritrea (Water and Food CP), Jordan, Morocco, Syria, Algeria and Yemen. Experiments on participatory research started recently in Mexico and Cuba
- Institutional strengthening and capacity building in all aspects of barley improvement

Future Plans

- Marker assisted selection (MAS) will be used in breeding for malting quality, for resistance to biotic stresses and possibly for cold tolerance. At the same time MAS will be made available to NARS.
- Research on grain end-use quality will be expanded, including malting, food uses, and nutritional quality (Iron, Zinc, and Vitamin A). Within the HarvestPlus Challenge Program, the barley project aims to improve the nutritional quality of barley for the benefit of the poor, particularly women and children.
- Research on salinity tolerance will be initiated in response to an increasing demand from national programs, in collaboration with NARS, and ARIs.
- Identification of chromosome regions responsible for adaptation to drought.
- Genomics of root morphology of landraces and wild relatives to develop strategies to cope with unpredictable water shortages.
- Extend training on participatory plant breeding.

Spring and Facultative/Winter Bread Wheat Germplasm Improvement for Increased Yield and Yield Stability in Central and West Asia and North Africa

Introduction

Bread wheat is the principal food source for the majority of the population in the CWANA region. Wheat consumption in CWANA is the highest in the world (about 185 kg/capita/year). Wheat provides over half of the calories consumed by people in the region and about half of the daily protein dietary intake. In CWANA wheat is cultivated in different agro-ecologies. However, about 50% of the total dryland wheat area in developing countries is located in the CWANA region and most (70%) wheat production in the region is under dryland. Due to the adverse effects of the harsh climatic and edaphic conditions and associated production constraints, including many abiotic (drought, cold and heat stress) and biotic (rusts, Septoria leaf blotch, Hessian fly, Sawfly, etc) stresses, productivity and total wheat production in the region is generally low and highly variable. The average yield of the region is about 1500 kg/ha; almost one half of the world average. Wheat production in CWANA has not kept pace with the increasing demand for wheat products. Being a strategic and economically import crop, research on wheat improvement was identified as a top priority by NARS. The project aims at achieving sustainable improvement in bread wheat productivity, yield stability and end-use quality for the benefit of resource-poor farm households in the region in partnership with NARS.

Achievements

- High-yielding and disease-tolerant elite germplasm were developed and made available to NARS.
- Sources of resistance to the major diseases and pest limiting wheat production in CWANA were identified and assembled as gene pools for breeding in collaboration with pathologists, entomologists, and NARS. These include sources resistant to rusts (leaf, stem and stripe rusts), Septoria leaf blotch, Hessian fly (HF), Russian Wheat Aphid (RWA) and Barley Yellow Dwarf Virus (BYDV).
- Elite lines of spring bread wheat suitable for flat bread (183 lines), raised bread (139 lines) and biscuits/pastry (129 lines) were identified, used in crossing program, and made available to NARS.
- A total of 42 spring bread wheat varieties were released in 11 countries and 21 facultative/winter wheat varieties were released in 7 countries in collaboration with NARS.
- The efficiency and accuracy of identifying differences among cultivars and assessing genotype by environmental (GxE) interaction were enhanced through the use of appropriate experimental design and field plot techniques, such as incomplete block design, and spatial and biplot analysis.
- The genetic base for biotic (Hessian fly, Septoria blotch, and Sunn pest) and abiotic (drought, cold and heat) stresses in spring bread wheat was broadened through

increased use of synthetics for the introgression of variability from both *T. tauschii* and durum wheat.

- Doubled-haploid techniques were used to speed up generation advance and for the development of mapping populations. Currently 4 populations are under development (HF, Yr, and Sr resistance and heat tolerance).
- Capacity of NARS for spring bread wheat improvement was strengthened through hands-on training, exchange of visits, workshops and consultancies. A total of 65 NARS researchers were trained.

Current Activities

- Spring bread wheat improvement focuses on semiarid rainfed and irrigated Mediterranean environments including low latitudes of CWANA, and improvement of facultative/winter wheat in irrigated and rainfed semiarid highlands and cold winter areas.
- Shuttle breeding to screen spring bread wheat and facultative/winter germplasm for adaptation to local biotic and abiotic stresses and to serve as early warning for incoming new virulence of biotic stresses in selected locations in CWANA.
- Breeding for rust resistance focuses on identification of slow rusting sources.
- Enhancing variability and broadening the genetic base of wheat in CWANA through extended exploitation of regionally adapted *Triticum* wild relatives, e.g. *Aegilops* via development of new generation of synthetic wheats and exploitation of novel genes for traits of interests (e.g. salt, Bo toxicity, and Zn availability).
- Use of doubled-haploid techniques to speed up generation advance and for the development of mapping populations.

Future Plans

- Integration of breeding with conservation agriculture: In the recent future, wheat production in CWANA is expected to shift from mono-cropping to a whole system approach under input-use efficient management technologies, such as raised bed planting systems and conservation agriculture. Under this scenario there is a need for changes in the breeding methodology to respond to the expected genotype X new management interactions and disease problems associated with microenvironments created by the new management systems.
- Bio-fortification: Improved nutritional quality including bio-fortification (pro-VitA, Zn, Fe, Mn)
- Salinity Tolerance: Research on salinity tolerance will be initiated, in collaboration with interested advance research institutes, to cater for the increasing demand from irrigated areas in CWANA.

Durum Wheat Germplasm Improvement for Increased Yield and Yield Stability in Central and West Asia and North Africa

Introduction

The CWANA region leads the world in durum wheat production. Durum is a traditional food crop in the CWANA with an annual per capita consumption of about 200 kg. Durum is used for pasta, *couscous,* and *burghul* products. Much of the planted area of durum is subjected to wide variation in environmental factors and much of the soils are marginal for agricultural production. In addition, there are numerous diseases and insect pests that limit crop productivity. The durum wheat breeding program conducts a broad-based genetics and plant breeding program in developing and distributing improved breeding lines to many NARS and ARIs, and providing training opportunities for NARS scientists and students.

Achievements

- Drought-tolerant and high-yielding durum varieties were developed in collaboration with NARS in Syria (Cham1, Cham3, and Cham5, Cham7, Douma1), covering more than 95% of the total area grown to durum in Syria. The adoption by Syrian farmers of these productive and stress tolerant durum cultivars along with improved agronomic practices has tripled its production in Syria. As a result, Syria has not only become self-sufficient in durum production, but also a major exporter of high quality durum grain in the region.
- Hessian fly and drought resistant durum cultivars were developed in collaboration with NARS in Morocco. Five Hessian fly and drought resistant durum varieties (INRA 1804, 1805, 1807, 1808, and 1809) were released.
- Leaf rust resistance in durum germplasm was bred which resulted in nearly 80% increase in leaf rust resistance of ICARDA's advanced durum germplasm.
- Resistance for *Septoria tritici* and root rots was incorporated in durum germplasm targeted to North Africa. Resistant lines were distributed to North African programs.
- Resistance to BYDV and RWA was transferred to drought tolerant durum lines and the resistant lines were distributed to national programs in CWANA.
- Lines resistant to multiple biotic stress resistance (rusts, *Septoria tritici*, root rots, BYDV, Russian wheat Aphid, Hessian fly, and stem sawfly) were developed and distributed to national programs in CWANA.
- Populations pyramiding resistance to Hessian fly were produced and distributed to the Morocco INRA program.
- One population for pyramiding resistance to drought using carbon isotope discrimination QTLs from different populations was generated
- Advanced germplasm and populations with salinity tolerance were identified and used in the breeding program. One mapping population (Omrabi5 x Belikh2) with drought x salinity tolerance was developed. Material for salinity tolerance was distributed to CWANA NARSs.

- High-yielding, drought-tolerant durum lines with improved micro-nutrient (Zn, Fe, and Mn) grain quality were generated from crosses with *Triticum* wild relatives (*T. dicoccoides, dicoccum, urartu,* etc.).
- In 2002, the collaboration between ICARDA and partners on durum research in dry areas received the Royal Award “Chevalier d’honneur” from the King of Morocco. Strengthened capacity of national partners through group and individual training of more than 50 research and extension personnel was achieved. Two M.Sc. and 5 Ph.D. students are currently conducting their dissertation research in the durum project.
- Research results were disseminated through one book and more than 80 reports, manuals, journal and newsletter articles published and/or presented at International Conferences and regional meetings.

Current Activities

- Germplasm development and use of landraces and wheat wild relatives to broaden the genetic base of the major biotic and abiotic stresses and grain quality with a major focus on drought, Hessian fly, *Septoria tritici*, and micronutrients.
- Development and distribution of improved germplasm combining yield potential, drought tolerance, and yield stability with improved processing and nutritional qualities, in addition to resistance to biotic stresses and temperatures extremes. Drought tolerance is addressed in collaboration with NARSs and ARIs through joint projects.
- Exploring means of improving efficiency in breeding methodologies and tools.
- Adoption of durum in marginal dryland though the IRDEN-project in Algeria, Morocco, Tunisia, Syria, and Turkey.
- Institutional strengthening and capacity building in all aspects of durum improvement.
- Durum genetics and genomics research: development of mapping populations for different agro-ecological environments and traits, of which three are mapped.
- Selection and evaluation: More than 12,000 segregating populations and around 2000 advanced lines are tested annually under 15 contrasting environments for water availability, temperature extremes, and hotspots for diseases and insects.
- Stress physiology research: The physiological traits linked to drought tolerance are used in selecting durum germplasm adapted to Mediterranean dryland using early growth vigor, fertile tillering, spike fertility, peduncle length, early maturity, and cold and heat damage at vegetative and reproductive stages as important selection criteria. For the advanced material and the recombinant inbred lines of mapping populations targeted for drought studies, relative water content, osmotic adjustment, isotopic carbon discrimination, canopy temperature, chlorophyll fluorescence, chlorophyll content, stomatal conductance, and photosynthesis are measured.
- Testing and distribution of parental lines, segregating populations, and advanced lines at 50 sites in the CWANA region**.**

Future Plans

- Adoption on a large scale of marker assisted selection (MAS) in the breeding for resistance to drought, heat, cold, and root penetration ability; tolerance to Hessian fly, leaf rust, *Septoria tritici*, and BYDV; gluten strength, yellow pigment (beta-carotene); and content of a-lipoxigenase, polyphenolase, and Zn and Fe. Extension of molecular breeding to major NARSs durum breeding programs.
- Continuation in identifying molecular makers linked with drought tolerance under different climatic conditions.
- Focus on incorporating salt tolerance in durum wheat and identifying the molecular markers linked to salt tolerance; increase collaboration with NARS and ARIs on salt tolerance.
- Identify the underlying mechanisms of drought adaptation in different landraces from different dryland agro-ecological zones.
- Extend training in drought resistance breeding, stress physiology, grain quality, and molecular breeding (mapping, QTLs, MAS).

Germplasm Improvement of Food Legumes

Introduction

Food legumes (chickpea, lentil and faba bean) are an integral part of farming systems in many developing countries. Being rich in protein, these crops serve as an important component of human food and animal feed, and by virtue of their ability to fix atmospheric nitrogen they contribute to improvement in soil health. ICARDA has the global mandate for lentil, faba bean and Kabuli chickpea improvement. ICARDA has conducted basic, applied and adaptive research to improve these crops. The major goal of the food legume improvement research is to increase the productivity and sustainability of the farming systems in partnership with national agricultural research systems (NARS), advanced research institutions, NGOs and farmers. This objective is pursued through development and delivery of improved genetic stocks (with resistance to various biotic and abiotic stresses) and improved production technologies, and sharing them with NARS. Some key accomplishments of the food legume research program at ICARDA are presented below. It is worth mentioning that ICARDA has a full fledged crop improvement program for lentil and Kabuli chickpea, and a pre-breeding program for faba bean.

Achievements

- High-yielding and disease tolerant varieties of lentil, chickpea and faba bean were released by NARS from improved genetic materials supplied by ICARDA. A total of 24 lentil varieties have been released in 13 countries (Afghanistan, Iraq, Pakistan, Nepal, Australia, Lesotho, Morocco, Tunisia, Lebanon, Syria, Turkey, Georgia, Ethiopia), 28 chickpea varieties in 14 countries (Australia, Azerbaijan, Ethiopia, Greece, Georgia, Iraq, Iran, Italy, Kazakhstan, Kyrgyzstan, Pakistan, Tunisia, Syria, and Turkey) and 21 faba bean varieties in 6 countries (Australia, China, Egypt, Ethiopia, Tunisia, and Mexico).

- Genetic base of food legumes was widened. Traits, which were not available in the landraces/cultivars, were introgressed using distant hybridization (with cultigens from diverse origin as well as with the wild species). In the Indian sub-continent, the narrow genetic base of lentil with respect to seed size, plant height and maturity was broadened through introgression of these traits into locally adapted materials and germplasm from West Asia and Latin American. Similarly, resistance to cyst nematode and cold tolerance, was introgressed from wild *Cicer* species to a cultigen of chickpea. In faba bean, *Orobanche* resistance, low tannin content, and independent vascular supply system were incorporated through recurrent selection.
- Resistant sources were identified and improved genetic stocks resistant to various biotic and abiotic stresses were developed and shared with NARS. Screening methods for evaluation of germplasm and breeding materials were developed in collaboration with pathologists, entomologists, virologists and shared with NARS. Elite and stress tolerant lines were developed and made available to NARS for evaluation. This helped in characterization of the variability in some pathogens to refine hybridization strategies at ICARDA. Major stresses included rust, Ascochyta blight, fusarium wilt, *Orobanche*, Sitona weevil; drought, cold and mineral imbalances in lentil; Ascochyta blight, fusarium wilt, cyst nematode, leaf miner; drought and cold in chickpea; and Ascochyta blight, chocolate spot, rust, Orobanche, and cold in faba bean.
- A mapping population for molecular marker study in chickpea was developed, and morphological and physiological characterization of drought tolerance in chickpea was initiated in collaboration with the Crop Development Center, University of Saskatchewan.
- Tall and lodging resistant varieties of lentil, chickpea and faba bean were developed to enhance mechanical harvesting. Examples of tall and lodging tolerant lentil cultivars released by NARS include: *Idlib-2*, *Idlib-3* and *Idlib-4* in Syria; *Hala* and *Rachayya* in Lebanon; *IPA-98* in Iraq; *Saliana* and *Kef* in Tunisia; and *Firat-87* and *Sayran-96* in Turkey in lentil.
- International public good products were developed and shared with NARS and the international community. These included genetic stocks, elite materials as finished products, technologies, methodologies, and information.
- Linkages were established with national and international governmental and private institutions such as ICRISAT, CIAT, Frankfurt University and Washington State University, University of Saskatchewan in Canada and CLIMA in Australia.
- Quality parameters were used as selection criteria. Basic quality parameters such as protein content, seed size and cooking quality were evaluated in the improved elite lines to maintain quality standards.
- The joint ICARDA/ICRISAT submission on chickpea improvement won the King Baudouin Award of the CGIAR in 2002.
- Participatory varietal selection methods were used to facilitate adoption of improved

cultivars. For example, a decentralized participatory breeding approach was initiated in lentil and chickpea in Syria; and lentil in Yemen, Eritrea, Nepal and Bangladesh.
- The program contributed to agricultural rehabilitation programs in Iraq and Afghanistan
- The program used advanced molecular research tools to improve breeding efficiency.
- Household income and food security were improved through adoption of the food legume technologies. Lentil production in Bangladesh increased by 28,000 tons per year, resulting in an economic return of approximately US$ 12.6 million annually from 2001 to 2005. In Nepal, adoption of improved lentil technologies resulted in a net return of about US$ 31 million over the past five years. Ethiopian farmers improved their lentil productivity with the cultivation of disease resistant varieties and that resulted in an annual income of about US$ 2 million annually. In Egypt, adoption of improved faba cultivars developed by NARS in collaboration with ICARDA resulted in an 11% increase in total production, whilst in Ethiopia total production increased by 57%.

Current Activities
- Development and distribution of early generation segregating materials, improved genetic stocks resistant to varying stresses, and elite lines with combined resistances and good agronomic and quality traits for targeted environments.
- Research on nutritional quality (enhanced Zinc and Iron content) in lentil, and low tannin content in faba bean, and large seed size in chickpea.
- Development of methodologies to enhance the effectiveness and efficiency of germplasm development and dissemination.
- Institutional strengthening and capacity building on different aspects of food legume improvement

Future Plans
- Expanded use of wild species in chickpea and lentil for enhancing of variability and broadening the genetic base.
- Bio-fortification to be expanded into chickpea and faba bean
- Genetic and molecular marker studies for selected stress traits.
- Research on high temperature tolerance in faba bean to be initiated in collaboration with NARS in Sudan.

Forage (Feed) Legume Germplasm Enhancement for Increased Feed and Food Production and System Productivity in Dry Areas

Introduction
Dry areas in Central and West Asia and North Africa (CWANA) regions are experiencing an increasing pressure on their agricultural resource base due to rapidly growing

livestock and human population. Shortage of animal feed is inflicting a heavy burden on the range lands, which are deteriorating. Severe feed and food deficits have also triggered the replacement of cereal-fallow rotation with continuous cereals, especially barley in dryland agriculture and increased cropping on marginal lands with attendant degradation of the soil resource base. Expansion of the cultivation of such legumes as vetches (*Vicia* spp.) and chicklings (*Lathyrus* spp.), which are indigenous to the region, can augment feed and food supply when sown either to interrupt the barley monoculture or to replace fallow in fallow-barley rotation. These species are sown and harvested in a single year and can be used for grazing during late winter and early spring, harvested for hay in spring, or carried to maturity for seed and straw. Their introduction in the rotation increases the productivity of food and feed and, therefore, the animal carrying capacity of the land in a sustainable manner. This is because of better maintenance of organic matter and nitrogen status of soil, improved soil physical conditions and better control of the diseases and pests as compared to continuous cereal rotations.

Achievements

- Nine improved *Vicia* spp. and *Lathyrus* spp. cultivars were released in different countries of CWANA. Farmer adoption of the improved cultivars in rotation with cereals reduced cereal monoculture resulting in increased crop and soil productivity.
- High-yielding and better quality common vetch lines were developed and tested on-farmers' fields and released as commercial verities.
- Improved grasspea lines with low grain levels of the neurotoxin β-ODAP (<0.1%), and tolerant to powdery mildew, aphids and broomrape were developed using conventional breeding methods and tissue culture technique. Somaclones with less than 0.06% β-ODAP were developed and tested on-station and on-farm. Quantities of seeds were distributed to farmers. Low-neurotoxin grasspea lines with white flower color and white-coated large-seeds were developed. These traits helped farmers to differentiate the low-neurotoxin lines from the high-neurotoxin lines with blue flower color.
- Low-neurotoxin grasspea somaclones were developed from Ethiopian and Bangladesh landraces and tested in multi-locational fields in Ethiopia.
- The Ethiopian Agricultural Research Organization (EARO) in collaboration with ICARDA released the first high-yielding and low-neurotoxin grasspea variety (*Lathyrus sativus* var. Waise). Since grass pea is the cheapest food legume for low income families and common component in their diet, the release of the low-neurotoxin varieties could reduce the fear from *neurolathyrism* in Ethiopia, and also in other grasspea producing countries like Bangladesh, China, Eritrea, India, Nepal and Pakistan.
- Improved self-regenerated amphicarpic vetch (*Vicia sativa* subsp. *amphicarpa*) with the potential for rejuvenation of marginal non-arable lands were identified and tested for marginal land improvement in Turkey, Armenia, Iran, Syria, and Egypt.
- The potential of underground vetch to regenerate naturally when grown in rotation with barley was demonstrated. This finding could have a significant impact on the ley farming system in dry areas.

- More than 40 research and extension staff of NARS were trained in forage legumes germplasm evaluation, breeding methodologies, selection criteria and quality assessments through either individual or group non-degree training. One M. Sc. and two Ph. D. students were trained.

Current Activities

- Selection and dissemination of high-yielding and better quality lines of *V. sativa, V. narbonensis, and V. dasycarpa.*
- Selection of *V. sativa, V. ervilia* and *V. panonica* lines adapted to the highlands of Iran, Turkey, CAC and alpine conditions in China.
- Selection and testing of high-yielding and grasspea lines with low grain β-*0DAP* content.
- Selection of grasspea lines with potential for either grain or fodder production.
- Studying the effect of grazing on seed bank dynamics of underground vetch.
- Assessment of the potential of underground vetch in management of degraded marginal lands.
- Farmer-participatory evaluations of promising pasture and forage legumes.

Future Plans

- Develop and disseminate feed legume germplasm with desirable traits for testing in collaboration with NARS. Focus will be on cold high-elevation environments in Iran, Turkey, Central Asia and the Caucasus and alpine grasslands of China where good progress has been made in increasing the cold tolerance character of *V. sativa, V. ervilia* and *V. panonica.* More emphasis will be given to the quality aspects and reduction of anti-nutritional factors (ANFs.), as well as resistance to insects and diseases.
- Grasspea improvement will focus on the development of high-yielding well adapted cultivars with low levels of neurotoxin in the grains. The feasibility of introgression of desirable characters from other closely related species such as *Lathyrus ciliolatus* will be also addressed. Reduction of grain neurotoxin content will be addressed by two main approaches: identification and elimination of enzymes responsible for β-ODAP production; and characterization and cloning of β-ODAP degrading gene from soil microbes, and transfer of genetic characters through inter-specific hybridization. The emphasis on grain yield will remain, but forage types will be selected. Enhancing the nutritional quality by reducing the β-ODAP content in the grain and improving the amino acid complement will also be given more attention.
- Research on the effect of environmental stresses, such as drought, zinc deficiency in soils and excess iron (F2++) or phosphate, which affects the level of β-*ODAP*, will continue.

Integrated Pest Management (IPM) in Cereal- and Legume-based Cropping Systems in Dry Areas

Introduction

ICARDA, recognizing the need to develop more sustainable production systems for both intensive and resource-poor farmers, places strong emphasis on genetic resistance to diseases and insect pests as the major control strategy for crop protection. Limited use of chemical pesticides is encouraged as an alternative, where host-plant resistance proves elusive. ICARDA is exploiting new opportunities for managing the production environment as a whole to promote plant health and to alleviate the constraints imposed by pests (including diseases, nematodes, and insects), within the framework of natural resource management. ICARDA's IPM research, over the last five years, focused on developing pest control/management strategies suitable for different agro-ecological zones and cropping systems in the Center's mandate region. Integrating host plant resistance, biological control, and crop management techniques in pest management has shown good results in various countries. IPM-pilot sites and farmer field schools have been adopted by ICARDA as a tool to support NARS collaborators to introduce IPM options to resource-poor farmers in CWANA. The goal is to improve productivity of cereals and legumes and reduce variability in production attributable to diseases and insect pests. The purpose is adoption by farmers of integrated pest management practices.

Major Achievements

- Diagnostic kits for viral diseases were developed and used by stakeholders: Diagnostic kits for the detection of viruses affecting cereal and legume crops in CWANA were developed and are widely used in field surveys and in seed health laboratories in CWANA for the detection of seed-borne viruses. Kits or antisera were made available, free of charge, for collaborators not only in CWANA, but also in Latin America, Australia and China. In addition, the Virology Lab at ICARDA routinely received thousands of plants/year blotted on nitrocellulose membranes from different CWANA countries for processing by tissue blot immunoassay (TBIA) test. Diagnostic tools to understand variability among ssRNA (*Luteoviruses*) and ssDNA (*Nanoviruses*) viruses that cause yellowing and stunting in food legume crops were developed. Generic degenerate primers were designed to detect a broad range of *Luteo*- and *Nanoviruses*. In addition, specific PCR protocols were developed for the sensitive detection of the known *Luteo*- and *Nanoviruses* of legumes.
- Role of natural enemies in IPM documented: Surveys were conducted to determine the role of natural enemies in the reduction of insect pests of cereals and legumes.
- Resistance of cereals and food legumes to diseases was characterized: Resistance to individual and multiple diseases was characterized within cereal and food legume germplasm core collections (with GRU), breeding nurseries (with breeders in MP2), and introductions (with NARS collaborators). Targeted material was recommended for specific sub-regions/countries. For example, in cereals, identification of Hessian

fly-resistant germplasm in wheat is targeted for North Africa, resistance to Russian wheat aphid and Barley yellow dwarf virus in wheat and barley was identified, and breeding lines carrying resistance gene(s) to these pests distributed to NARS collaborators. Multiple disease resistance that combines resistance to foliar and seed borne diseases was identified in barley, and combined resistance to rusts, Septoria and Sunn pest has been identified in wheat breeding lines. Multiple disease resistances in food legumes was identified in lentils for wilt and for three viruses, rust and Ascochyta blight and in chickpea mainly for wilt and Ascochyta blight. Pathotypes/races in wheat rusts, barley powdery mildew and chickpea Ascochyta blight were characterized and used for screening under artificial inoculation. For barley scald, Fusarium wilt of lentil and yellowing viruses of legumes, genetic characterization of the causal agents was conducted. Biotypic variation of Russian wheat aphid and Hessian fly populations was characterized in WANA.

- Best-bet IPM packages were developed and tested on-farm: IPM packages were refined and evaluated jointly with different national programs at farm level depending on the expertise and priorities in the different agro-ecological zones and farming systems. Best-bet IPM options were developed and tested at the farm level at various pilot sites in CWANA These included: Hessian fly (early planting, genetic resistance), chickpea Ascochyta blight (seed treatment, genetic resistance, delayed sowing, proper plant density and minimal foliar spray), faba bean necrotic yellows virus (sowing date, seed rate, chemical control, rouging of infected plants, improved cultivars), *Orobanche* parasitic weed (delayed planting, early maturing genotypes adapted to late planting and timely chemical spray), chickpea leaf miner (early planting, tolerant varieties, botanical pesticides). In the case of Sunn pest, the options included the use of the revised economic threshold for insecticide spraying, the change of spraying policy from aerial to ground, the devolution of control to farmers, the use of early maturing varieties and early harvesting. Other novel options such as the use of entomopathogenic fungi are in the last stages of development and should be made available to farmers for use in the next few years. Conservation of natural enemies, in particular the egg parasitoids through proper pest scouting and the judicious use of chemical insecticides at the farmer level is the focus at the IPM pilot sites. The control of stubble borne diseases in wheat and barley (Septoria leaf blotch, tan spot, scald, and net blotch) was improved by the integration of host resistance (including variety mixture) with appropriate crop rotation and adjustment of planting date and fertilizer application.
- Capacity of partners to undertake research-for-development was strengthened: A large number of farmers, extension agents and research technicians were trained through Farmer Field Schools (FFS) approach and non-degree specialized courses. Eleven M.Sc. and 12 Ph.D. students conducted their dissertation research at ICARDA. Expert systems and e-learning modules were developed in collaboration with other ICARDA projects, CLAES, IRRI and ICRISAT. Four international and/or regional workshops were organized.

Current Activities

- **Cereals (barley, durum wheat, spring and facultative winter bread wheat):** Evaluation of a wide array of germplasm of cereals, including wild relatives, for new sources of resistance to diseases (*BYDV*, wheat yellow and stem rust, scald of barley) and insect (Russian wheat aphid, Sunn pest and barley stem gall midge) pests. Characterization of breeding nurseries and subsets of at least 500 accessions of crop wild relatives (*Hordeum spontaneum*, *Triticum* sp., and *Aegilops* sp.) for reaction to *Barley yellow dwarf virus 'BYDV'*, wheat yellow 'YR' and stem rusts 'SR', barley scald 'SC' diseases, and for Russian wheat aphid 'RWA', Sunn pest 'SP', and Barley stem gall midge 'BSGM' insect pests. Evaluation of germplasm for resistance to economic diseases in CWANA under artificial inoculation in Syria, Turkey, Ethiopia, Morocco, Tunisia and Iran.
- **Food legumes (chickpea, lentils, and faba bean**): Evaluation of different subsets of crop wild relatives/ landraces and breeding lines for resistance to diseases (fababean yellow mosaic virus, *chocolate* spot, chickpea Ascochyta blight and lentil fusarium wilt) and insect (leaf minor in chickpea and Sitona in lentils) pests.
- **Determination of diversity in diseases and insect pests:** Virulence surveys and pathogenicity spectrum investigated, and characterization of variability of two virus groups (luteovirus, nanovirus), four fungal diseases (wheat yellow rust, barley scald, chickpea Ascochyta, and lentil fusarium wilt); and two insect pests (Russian wheat aphid and Sunn pest). Characterization of fungal, viral, and insect populations using DNA finger printing; identification of yellow rust races and scald biotypes for Syrian isolates at the ICARDA headquarters and at DIAS Denmark (yellow rust populations from CWANA). Molecular and morphological characterization of wheat yellow rust, barley scald, Russian wheat aphids and Sunn pest in cereals; and Ascochyta blight and fusarium wilt in food legumes. Development and testing of serological and molecular tools and viral diagnostic kits with partners in Iran, Tunisia, Syria and Ethiopia. Testing of disease and insect control options at 'hot-spots' and pilot sites in CWANA.

Future Plans

- Identify new effective resistance genes or gene combinations for fungal, viral and insect pest of cereals and legumes.
- Assist in the implementation of marker-assisted selection in screening for disease resistance.
- Develop germplasm pools for multiple and durable disease resistance through screening of breeding material under artificial inoculation using relevant virulence genes.
- Further characterization of resistance among wild relatives and landrace cultivars using available markers in host crops and prevalent pathotypes/races in fungal populations.
- Expand work on the pathotyping/biotyping/serotypes and molecular characterization of fungal, viruses and insect populations of cereals and food legumes through closer collaboration with Advanced Research Institutes and universities.
- Expand research on biological control, especially insect pests, through the use of entomopathogenic fungi.

- Progressively decentralize most of the disease and insect pest screenings to NARS to exploit known hot spots that can serve a well defined agro-ecological zone within CWANA.
- Expand the implementation of IPM through FFS in close collaboration with NARS and other institutions dealing with research for development issues such as FAO, NGOs, etc.
- Investigate the influence of additional agronomic practices on IPM options/packages, including supplementary irrigation, residue management and plant nutrition.
- Evaluate the impact of IPM packages/options in collaboration with socio-economists.
- Reactivate and improve research on legume and cereal soil borne-pathogens (nematodes, root rots) through collaboration with NARS and advanced research institutions.
- Adapt and improve diagnostic kits for virus detection and identification.
- Improve the quality of training of research support staff at HQ, in country, and regional levels.
- Improve graduate degree training programs through linkages with universities in Australia, North America, Europe, and Japan.

Use of Biotechnological Tools for Enhanced Germplasm Improvement in the Dry Areas

Introduction

The goal of the project is to increase production of cereals (barley and wheat) as well as feed (lathyrus) and food legumes (lentil, kabuli chickpea, and faba bean) through the exploitation of novel bio-technologies that improve the efficiency of the development of germplasm adapted to the biotic and abiotic stressed environments of the dry areas. The outputs are: 1) tissue culture derived improved barley and bread wheat and feed legume germplasm, 2) genetic resources of ICARDA mandate crops finger-printed using non-radioactive DNA technology including DNA-marker system, 3) genes incorporated into legumes and cereals using transformation technology and genetic engineering, and 4) strengthened capacity of NARS through individual and group training and research project activities A summary of achievements, current activities and future plans for each output is presented below.

Achievements and Future Plans

Output 1: Tissue culture-derived barley, bread wheat, and grasspea germplasm developed

Achievements

- Anther- and isolated microspore culture systems were used for the development of doubled haploid lines for barley and wheat at headquarters and in national programs.

- In wheat, DH lines were produced of crosses with introgression of Hessian fly resistance for North Africa and yellow rust resistance into adapted germplasm.
- In 2004, two DH lines developed in collaboration with partners in Sudan were suggested for release.
- The physical infrastructure was upgraded through construction of three more walk-in growth chambers ($12m^3$)
- Somaclones in *Lathyrus* exhibiting enormous variation for a number of breeding objectives including the neurotoxin 3-(N-Oxalyl)-L-2, 3-diaminopropionic acid (β-ODAP) were developed.

Future Plans

- Shift from F_1 to selected F2 and F3 plants should increase efficiency of the use of DH lines

Output 2*: *Genetic resources of ICARDA mandate crops finger-printed using non-radioactive DNA technology

Achievements

Funding was obtained for four restricted projects, namely: 1) Allele Mining Based on Non-Coding Regulatory SNPs in Barley Germplasm, 2) Genetic Characterization of Barley, Lentil, Chickpea, and Institutional Bioinformatics Capacity Building, 3) Exploration of Genetic Resources Collections at ICARDA for Adaptation to Climate Change: Identification and Utilization of Sources of Stress Tolerance, and 3) Functional Genomics of Drought and Cold Tolerance in ICARDA-mandated Legumes: Chickpea and Lentil

Genetic Resources Evaluation

- About 10,000 plant genetic resources were characterized with support from the Generation Challenge Program (GCP)
- Laboratory Information System (LIMS) integrated with the Germplasm Management Systems in ICIS (GCP) was developed
- About 300 *H. spontaneum* accession with SSR and DART markers were characterized and evaluated for six biotic stresses in collaboration with Minnesota University (Comparative Genomics Initiative)
- 228 barley lines were characterized for their adaptation to drought, with SSR, SNP and DaRT markers (1000) for association mapping (BMZ project)
- Linkage block analysis was conducted on *H. spontaneum* derived lines in collaboration with CRC, Adelaide.
- Major barley lines were characterized for drought parameters using physiological descriptors
- Affymetrix barley chip was used to identify drought induced barley genes
- Syrian Awassi sheep were characterized using SSR markers

Markers, Maps, and MAS

- SSR markers were used to characterize chickpea germplasm collections, to develop linkage maps, and to tag Ascochyta blight and fusarium wilt resistance.
- SSR markers were developed for lentil in collaboration with Kiel University, Germany. The markers were used to characterize lentil germplasm, to develop linkage maps, and to tag fusarium wilt resistance and cold tolerance.
- A quantitative trait locus for a drought tolerance trait was identified in barley using SSR markers in collaboration with the Cooperative Research Center (CRC) in Adelaide, Australia.
- Marker-assisted selection was used for barley (*Rynchosporium secalis,* Yd2,) and chickpea (Ascochyta blight).
- Pathogen (*Rynchosporium secalis*) and pest (Hessian fly) populations were characterized and geographical distribution maps developed.
- Allelic imbalance assay was used to test allelic expression of barley genes

Future Plans

- Develop SSR markers for faba bean and map them into two RIL populations (GCP)
- Sequence candidate genes across a barley reference sample (300 lines) (GCP)
- Transfer MAS for Yd2 and scald to Morocco and Jordan (GCP)
- Apply more MAS marker assays for barley and wheat
- Develop marker assays for stem rust and yellow rust in wheat
- Characterize sheep and goats using fluorescent labeled SSRs and SNP markers
- Analysis of reference samples for Linkage Disequilibrium and Association Mapping with Structure, Darwin and Tassel

Output 3: Genes incorporated into legumes and cereals using transformation technology and genetic engineering

Achievements

Funding obtained for two research projects: 1) Integrating regional expertise in biotechnology for sustainable exploitation of plant genetic resources in the Mediterranean region, and 2) Molecular marker assisted selection and genetic engineering of ICARDA mandated crops.

- An Agrobacterium-mediated transformation system in chickpea was developed with the University of Hanover, Germany; and a similar system for lentil was licensed from the Centre for Legumes in Mediterranean Agriculture (CLIMA), Australia. Both were established at ICARDA in collaboration with the Agricultural Genetic Engineering Research Institute (AGERI) in Cairo, Egypt.
- Biolistic transformation systems in barley, durum wheat and bread wheat were developed for ICARDA varieties at AGERI in Cairo, Egypt
- Fungal resistance (*pHKvst-1*, anti-fungal proteins) and abiotic stress resistance (*DREB1A*) were transferred to chickpea and lentil.

Future Plans

- Transgenics will be tested in a fenced gene-flow area 40 x 80m in collaboration with the Syrian National Biosafety Committee.
- Cereal transformation will be initiated at ICARDA in 2006.
- More constructs for abiotic stress resistance will be tested in legumes and cereals.

Output 4: Capacity of NARS strengthened through individual and group training and research project activities

Achievements

Funding was obtained for two projects on capacity building: 1) Development of biotechnological research in the Arab States, funded by the Arab Fund for Social and Economic Development (AFSED), Kuwait, 1998-2001, and 2) Third country training program for enhancing human resource development in Iraq, short-term training courses for DNA marker technology and genetic engineering, 2005-2009, JIRCAS, Japan.

- Training courses on "DNA marker technology for crop improvement" were held in Syria, Sudan, Iran Morocco, Algeria, and Oman.
- Training course on "Wheat transformation" was held jointly with Dr. A. Pellegrineschi, CIMMYT in Karaj, Iran.
- Training courses on biosafety were held at AGERI, Cairo, Egypt in 2002 and in Damascus/Aleppo in 2003.

Future Plans

- Training course on "DNA Marker Technology for Crop Improvement" funded from JICA is being held at ICARDA headquarter mainly for trainees from Iraq
- Training course on "Transformation Technologies and Genetic Engineering" funded from JICA will be held at ICARDA headquarters mainly for trainees from Iraq for the first time in 2006
- Shift training activities from data generation to data analysis using appropriate modules.

International Crop Information System

Crop Information System development at ICARDA is addressing issues consistent with the objectives and goals of the CGIAR initiative on International Crop Information System. The plan is to implement ICIS for all the ICARDA mandate crops (barley, bread wheat, durum wheat, chickpea, lentil and faba bean). The listed activities below have been implemented for barley, chickpea and lentil but will subsequently be extended to the other crops. The ICIS initiative involves:

1. Genealogy Management (Characterization, nomenclature)
2. Data Management (Evaluation, molecular, geographic)

3. Molecular Data Integration: Laboratory Information System (LIMS) and Gene Management System (GEMS). ICARDA is collaborating on GCP SP4 C1)
4. In collaboration with MP6, make all database web-enabled

ICIS GMS (Genealogy Management System) was implemented for barley, chickpea and lentil by December 2005. Integration and evaluation of molecular data are ongoing.

Human Resources Development

As shown in Table 1, a total of 1491 research and extension staff were trained in various areas under the Integrated Gene Management Project.

Table 1. Integrated Gene Management Project: Human Resource Development Profile, 2000-2005

Year	Group Courses (Aleppo)	Specialized Courses (Aleppo)	In-country Courses	Visiting Scientist	Graduate Students
2000	4	58	51	52	31
2001	26	46	33	59	37
2002	18	53	42	75	40
2003	37	40	64	75	36
2004	27	37	115	75	29
2005	55	38	127	77	34
Total	167	272	432	413	207

Grand Total 1491