

## Megaproject 2: Integrated Gene Management: Conservation, Enhancement and Sustainable Use of Agrobiodiversity in Dry Areas

### Rationale

The Central and West Asia and North Africa (CWANA) region contains three major centers of plant diversity, where numerous species of temperate-zone agriculture originated and were first domesticated and where their wild relatives and landraces are still found, including cereals (wheat, barley, oats and rye), food legumes (chickpea, lentil, faba bean and pea), oilseeds, vegetables, fruits and nuts, forage and pasture species, and herbs, aromatic and medicinal species. The region also retains considerable biodiversity of small ruminants (sheep and goats) where they were first domesticated. Dryland species exhibit a wide range of adaptation to prevailing abiotic and biotic stresses. The conservation of their biodiversity will serve as a valuable source of genetic material for future germplasm enhancement.

However, these genetic resources are being eroded through the degradation of their natural habitats, intensification of the cultivation of arable lands, expansion of cultivation into marginal areas, and overgrazing in natural rangelands. Addressing the current situation in the developing countries of CWANA is of global importance. Erosion of the biodiversity in the region is threatening the ancestors, wild relatives and landraces of agriculturally important species, as well as the associated insects (pests and predators) and micro-organisms, needed in the future as sources of resistance to biotic and abiotic stresses. In this respect, CWANA represents a natural gene bank providing sources of heat and drought tolerance for world agriculture.

ICARDA has both global and regional crop mandates. It has a global responsibility in barley, lentil and faba bean, and regional responsibility within CWANA for the improvement of durum and bread wheat (in cooperation with CIMMYT), kabuli chickpea, and forage and pasture crops. Wheat is the principal cereal grown in the region and is the staple food in most countries, accounting for 45% of the region's per capita calorie intake. This dependency on wheat is even higher in the Central Asia and Caucasus region, where it contributes 60% of calories in some countries. Production of wheat is not adequate to satisfy the demands of the rapidly growing populations. As a result, substantial imports are made every year to meet the deficits. North Africa alone imported a total of almost 11 billion MT of wheat in 2001. Barley is the principal feed for small ruminants, but is also an important food source in some countries. Pulses provide a valuable source of protein, particularly in the poorer countries such as Eritrea and Ethiopia, where they provide up to 20% of dietary protein, and among the poorest consumers (both urban and rural) in other countries. They are also an important subsistence commodity for many farm households. Improvement in the production of ICARDA's mandate crops, through germplasm enhancement, will therefore contribute substantially to food security in the region.

The *ex situ* collections developed and maintained by this project allow continuous and reliable access to the genetic resources required to develop improved germplasm. The exploitation of these genetic resources through breeding for the benefit of the poor is recognized as a key comparative advantage of ICARDA and other Centers in the CGIAR. At the same time *in situ* conservation, through protection and habitat management, maintains naturally occurring and evolving populations of agriculturally useful species within their environment. Innovative approaches to *in situ* and on-farm conservation are needed that maintain the productive capacity and economic livelihoods of the communities involved, and take account of the social, economic and environmental constraints which determine their land use practices. Where appropriate, incentive or compensatory policy measures need to be developed to support and encourage the adoption of measures for the conservation, management and sustainable use of biodiversity.

New approaches and tools offer new opportunities for the development of more effective and efficient breeding methods for unpredictable environments. Landraces, developed over the centuries by farmers' selection for desirable traits, are usually genetically more heterogeneous and highly adapted to their specific agro-ecological environment. Farmers' indigenous knowledge and their criteria for selection are integrated into germplasm enhancement through participatory approaches.

Rapidly evolving biotechnological tools for the characterization and evaluation of genetic resources, and for identifying specific traits of value to crop improvement programs, are combined with conventional

breeding approaches to develop improved germplasm with higher and more stable yields, better resistance to evolving biotic and abiotic stresses (particularly drought and heat), including those emanating from climate change, and better end-use and nutritional quality.

### **Project Description**

The project goal, purpose, outputs, output targets and associated expected outcomes and impacts are provided in the attached “Project Impact Pathway” matrix. Assumptions and external conditions associated with outputs, outcomes and impacts are listed in the introduction to the Project Portfolio.

Major elements of MP2 comprise:

- Collection, acquisition, documentation and *ex situ* conservation of the genetic resources of ICARDA mandate crops.
- Agro-morphological and molecular characterization and evaluation of *ex situ* collections for traits relevant for use in germplasm enhancement.
- Characterization of major pests and identification, testing and conservation of bio-agents for the control of major pests and pathogens.
- Phenotypic characterization and evaluation of small ruminant breeds in CWANA.
- Development and testing of options for sustainable management of agro-biodiversity in its original habitat; documentation of local knowledge and indigenous management practices and uses regarding plant and animal genetic resources; and development of plant genetic resources legislation and institutional and policy options to support *in situ* and on-farm conservation and sustainable use of the biodiversity of agriculturally useful plant species.
- Identification and use of wild relatives, landraces and other genetic stocks to broaden the genetic base of cereals and legumes.
- Germplasm enhancement for higher and more stable yield, improved end-use and nutritional quality, better biotic and abiotic stress resistance and adaptation to climate change (in cooperation with *HarvestPlus* and *CP Generation*).
- Development, and transfer to NARS, of biotechnological tools for breeding for resistance/tolerance to biotic and abiotic stresses: doubled haploid breeding, development of marker assisted selection, use of transformation technology and genetic engineering to incorporate genes of interest into cereals and legumes (in cooperation with *CP Generation*).
- Development of methodologies to enhance the effectiveness and efficiency of germplasm development and dissemination.
- Institutional strengthening and capacity building in all aspects of integrated gene management.

The improved germplasm developed within ICARDA’s breeding programs are disseminated to NARS partners through the Center’s International Nurseries Network, which in 2004 included 63 countries with 123 collaborators, 2087 trial sets and the distribution of approximately 200,000 seed packets. The evaluation data returned by these collaborators contribute to the knowledge base maintained by ICARDA. ICARDA maintains a specialized Seed Production Unit, which is responsible for the production of foundation seed for use by national plant breeding and seed multiplication programs.

The project encompasses intra-Center linkages as follows:

- Drought tolerant germplasm developed within MP2 is utilized by MP1 in integrated research on water use efficiency and drought mitigation.
- Germplasm with better end-use characteristics and/or enhanced nutritional quality developed within MP2 is utilized within MP4 in research on income-generating options through post-harvest processing and added value of crop products.

- Improved forage legume germplasm developed within MP2 is utilized in research on integrated feed/livestock production systems within MP4.
- MP1 works closely with MP5 in analyzing the factors affecting adoption of improved germplasm, on *ex ante* and *ex post* assessments of the impact of ICARDA's germplasm enhancement, and in developing institutional and policy options to support *in situ* conservation of agrobiodiversity.
- MP6 includes research on strengthening formal and informal seed production and delivery systems, ensuring that the products of MP1 research reach farmers.

### **Target Eco-region**

Target ecoregions are related to ICARDA's crop mandates: global for barley, lentil and faba bean; and for wheat, kabuli chickpea and forage legumes, CWANA and other dry areas where the crops are important. These crop mandates essentially encompass five ecoregions:

- the lowland subtropics with cool winter rainfall (Mediterranean type);
- the warm, seasonally dry, subtropics with summer rainfall;
- the highland subtropics with (often cold) winter precipitation, and highland areas in the tropics where ICARDA's crops are grown;
- the seasonally dry tropics in Central and West Asia and North Africa (CWANA);
- the dry temperate areas.

### **Users and Beneficiaries**

*Users:* The principal users are NARS crop improvement programs, which will benefit from improved efficiency of germplasm enhancement for dry areas and from the conserved and documented genetic resources.

*Beneficiaries:* The sustainable livelihoods of farmers, especially resource-poor farmers in dry areas, will improve from adoption of improved varieties specifically adapted to their conditions. Livestock owners in marginal lands, who include forage crops in rotations in place of continuous cereal cropping, will benefit through increased feed supply for livestock. Consumers will benefit from improved nutritional quality and the low prices of end products.

### **Collaborators**

- *National Programs:* National research and extension programs in Central and West Asia, North Africa, sub-Saharan Africa (Eritrea, Ethiopia, Mauritania, Sudan), Latin America (Argentina, Ecuador, Mexico, Peru, Uruguay), South and East Asia (Bangladesh, China, India, Korea, Nepal, Pakistan, Vietnam), and Southern Europe.
- *Australia:* University of Brisbane; University of Adelaide; Cooperative Research Centre for Molecular Plant Breeding; Southern Cross University; Cooperative Research Centre for Innovative Grain Food Products; Center for Legumes in Mediterranean Agriculture (CLIMA), Perth; University of Western Australia; NSW Department of Primary Industry, Tamworth, NSW; Victorian Institute of Dryland Agriculture, Horsham, Victoria; University of Sydney, Plant Breeding Institute, Cobbity, NSW; and Australian Winter Cereal Collection, Tamworth.
- *Austria:* University of Natural Resources and Applied Life Sciences (BOKU); the Federal Institute of Agrobiology (FIA).
- *Belgium:* University of Ghent.
- *Canada:* Agriculture Canada, Laval University, McGill University, University of Saskatoon, University of Alberta.
- *Denmark:* Risoe National Laboratory; Danish Institute of Agricultural Sciences (DIAS).
- *Egypt:* Agricultural Genetic Engineering Research Institute (AGERI), Cairo; Matrouh Resource Management Project (MRMP), Marsa Matrouh.

- *France*: Paris Sud University, INRA.
- *Germany*: University of Hamburg, University of Hohenheim; University of Frankfurt; IPK Gatersleben.
- *India*: National Bureau for Plant Genetic Resources (NBPGR); Indian Agricultural Research Institute (IARI).
- *Italy*: University of Bologna, Tuscia University, Institute of Nematology, Bari.
- *Japan*: JICA; JIRCAS; University of Kyoto.
- *Jordan*: University of Jordan, Jordan University of Science and Technology (JUST).
- *Morocco*: INRA; University Hassan II.
- *Russia*: All Russian Institute of Agricultural Biotechnology; N.I. Vavilov Research Institute of Plant Industry (VIR), St Petersburg.
- *Spain*: University of Barcelona, University of Lerida, IRTA-Lerida, University of Cordoba
- *Switzerland*: Swiss Centre for International Agriculture (ZIL), Federal Institute of Technology Zurich (ETHZ); Federal Research Station for Plant Production (RAC).
- *Syria*: Aleppo University; Damascus University; Tishreen University.
- *UK*: Scottish Crop Research Institute; CABI Bioscience; University of Birmingham.
- *USA*: North Dakota State University; Oregon State University; Colorado State University; Kansas State University; Oklahoma State University; University of Missouri; University of Minnesota; University of Vermont; University of Wisconsin-Madison; USDA-ARS Washington State University; Cornell University; Purdue University; Minnesota State University; University of California (Davis).
- *International partners*: FAO; CIHEAM (International Centre for Advanced Mediterranean Agronomic Studies).

### **System Linkages**

- ICARDA and CIMMYT cooperate in facultative and winter wheat improvement within the IWWIP (International Winter Wheat Improvement Program) with Turkey, and in barley improvement for Latin America.
- ICARDA and ICRISAT cooperate in the genomics of chickpea within the CP generation.
- **Challenge Programs:** ICARDA participates in all three Challenge Programs (specific cooperation is indicated in the logframe):
  - *Challenge Program on Water and Food*, through a project on “Improving Water Productivity of Cereals and Food Legumes in the Atbara River Basin of Eritrea” (with CIAT).
  - *HarvestPlus*: on biofortification of barley, lentils and wheat.
  - *Generation*: ICARDA is a partner in the Generation Consortium.
- **Systemwide Programmes and other CG Consortia:** ICARDA participates in the following programs (specific cooperation is indicated in the logframe):
  - ICARDA is the convening center for the Ecoregional Program for Central Asia and the Caucasus, and participates in other programs as follows:
    - Systemwide Program on Participatory Research and Gender Analysis System (PRGA).
    - Systemwide Livestock Program (SLP).
    - Systemwide Program – Integrated Pest Management (SP-IPM).
    - Systemwide Genetic Resources Research Programme (SGRP) and SINGER.
    - International Crop Information System (ICIS).

## MTP 2006–2008:Project Impact Pathway

<b>Project</b>	<b>MP2: Integrated Gene Management: Conservation, Enhancement and Sustainable Use of Agrobiodiversity in Dry Areas</b>
<b>Goal</b>	Sustainable conservation and use of agrobiodiversity to increase agricultural production in the dry areas
<b>Purpose</b>	Improved livelihoods of resource poor farmers from the conservation, improvement and sustainable use of agrobiodiversity of plants and animals and the adoption of improved varieties and associated technologies.

	<b>Outputs</b>	<b>Intended Users</b>	<b>Outcomes</b>	<b>Impact</b>
<b>OUTPUT 1</b>	Genetic resources of barley, wheat, lentil, chickpea, faba bean and feed legumes and their wild relatives conserved <i>ex situ</i> with their genetic diversity characterized and documented for relevant traits  Options for <i>in situ</i> conservation of agrobiodiversity available for users	NARS crop improvement and genetic resource conservation programs	Increased conservation and availability of agrobiodiversity	Threat from genetic erosion reduced in dry areas
<b>Output Targets 2006</b>	Collection mission conducted in Kyrgyzstan  Sub-sets of wheat and barley accessions collected from drought-stressed sites identified using GIS.	ICARDA and NARS crop improvement and genetic resource conservation programs  ICARDA and NARS plant breeders	Accessions conserved in national gene bank and safety duplicated at ICARDA.  New drought tolerant genetic materials identified and included into ICARDA and NARS screening and breeding programs	Gaps in global collections of Central Asian field crop genetic resources filled.  Greater genetic variability available to crop improvement efforts.  Stable performance of cultivars in the farmers' fields and reduced risk for drought affected farmers
	On-farm phenotypic characterization of at least 30 small ruminant breeds in CWANA documented	ICARDA and NARS livestock improvement programs	Information used by NARS in selecting breeds adapted to specific conditions, for improved productivity of various end products and specific market orientation	More productive and remunerative livestock enterprises
<b>Output Targets 2007</b>	Global database of wheat wild relatives available on internet	CG Centers, international and NARS researchers	Genetic base widened through increased use of wheat wild relatives in wheat breeding programs	Reduced variability of yield in the farmers' field and reduced risk for farmers
	Sub-sets of lentil accessions collected from drought-stressed sites identified using GIS	ICARDA and NARS plant breeders	New drought tolerant genetic materials identified and included into ICARDA and NARS screening and breeding programs	Stable performance of cultivars in the farmers' fields and reduced risk for drought affected farmers

	Outputs	Intended Users	Outcomes	Impact
	Genetic diversity of composite subsets (3,000 barley, 3000 chickpea and 1,000 lentil accessions) characterized using molecular markers ( <i>CP Generation</i> )	CG Centers, international and NARS researchers	New genetic material classified and included in breeders' collections for use	Wider range of cultivars grown in farmers' fields, increasing diversity and reducing risk
<b>Output Targets 2008</b>	At least 1500 accessions of wild relatives, landraces and advanced lines of wheat, barley, lentil and chickpea characterized for reactions to major diseases and insects	ICARDA and NARS plant breeders	Disease and insect resistance incorporated into breeding material	Genetic vulnerability and risk from pests and diseases reduced in the farmers' fields
	Sub-sets of chickpea accessions collected from drought-stressed identified using GIS	ICARDA and NARS plant breeders	New drought tolerant genetic materials identified and included in ICARDA and NARS screening and breeding programs	Stable performance of cultivars in the farmers' fields and reduced risk for drought affected farmers
<b>OUTPUT 2</b>	Improved genetic stocks of barley, wheat, and cool season food and feed legumes developed through conventional, biotechnological (molecular markers) and participatory breeding distributed to NARS through international nurseries	NARS plant breeders	Increased availability of improved genetic material of mandate crops	Improved farm production and rural livelihoods
<b>Output Targets 2006</b>	30–50 drought tolerant barley, bread wheat, and food and feed legume lines and associated crop management options evaluated with NARS	NARS	Increased availability of drought tolerant genetic material to NARS researchers for drought prone areas	Livelihoods in drought prone areas improved and reduced risk for farmers
	50 new barley lines with <i>Fusarium</i> head blight resistance and malting quality distributed in Latin America	NARS	Increased availability of improved malting barley	Productivity of barley increased in farmers' fields resulting in increased income and reduced risks for farmers
<b>Output Targets 2007</b>	Identification of barley and lentil germplasm with high concentration of $\beta$ -carotene, iron (Fe) and zinc (Zn) and their utilization in breeding program ( <i>CP HarvestPlus</i> )	ICARDA and NARS plant breeders	New genetic material of barley and lentils with high concentration of micronutrients available	Adoption of micronutrient-dense lentil and barley varieties will lead to improved health and livelihoods of poor farmers
	Grasspea germplasm with safe level of neurotoxin ( $\beta$ -ODAP) identified	NARS plant breeders	Low-toxin grasspea lines available to researchers	Adoption of low-toxin varieties will lead to reduced risk to drought exposure and improved human health

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<b>Output Targets 2008</b>	Transformation technology and genetic engineering tools utilized to incorporate genes into food legumes	Biotechnologists and plant breeders	Enhanced availability of drought tolerant chickpea and lentil lines	Higher productivity in farmers fields and reduced risk to producers
	At least 500 double haploid lines of bread wheat and barley produced and evaluated in Syria for yield and quality	Plant breeders	Rapid availability of homozygous lines of barley and bread wheat	Farm incomes improved and risks reduced through fast turnover of varieties
<b>OUTPUT 3</b>	Foundation seed of improved varieties and advanced lines of barley, wheat, and food and feed legumes available to NARS	National seed production programs	Increased availability of seed of improved varieties of mandate crops	Improved farm production, reduced losses and risks due to availability of quality seed of improved varieties
<b>Output Targets 2006</b>	30 tonnes of seed of 20 varieties of cereals and legumes produced, treated and supplied to NARS	National seed production programs	Increased availability of high quality seed for national seed production programs and/or to restore productive capacity in agricultural rehabilitation programs	Improved farm production, reduced losses and risks due to availability of quality seed of improved varieties
<b>Output Targets 2007</b>	30 tonnes of seed of 20 varieties of cereals and legumes produced, treated and supplied to NARS	National seed production programs	Increased availability of high quality seed for use in national seed production programs and/or to restore productive capacity in agricultural rehabilitation programs	Improved farm production, reduced losses and risks due to availability of quality seed of improved varieties
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<b>OUTPUT 4</b>	Enhanced capacity of human resources in NARS to improve integrated gene management	NARS	Increased efficiency of research from improved capabilities of NARS researchers	Improved livelihoods result from improved flow of outputs from NARS research on integrated gene management

	<b>Outputs</b>	<b>Intended Users</b>	<b>Outcomes</b>	<b>Impact</b>
<b>Output Targets 2006</b>	20 NARS scientists trained in specific aspects of integrated gene management (genetic conservation and documentation, breeding for biotic and abiotic stresses, participatory plant breeding, advanced statistical techniques and data management, molecular techniques and double haploid breeding and biosafety)	NARS scientists	Increased capability of NARS scientists in new techniques leading to enhanced efficiency and effectiveness of research	Increased farm production and incomes from use of NARS research outputs
	5 M.Sc. and Ph.D. students complete their research under joint supervision by ICARDA scientists	NARS researchers	Increased availability of specialists in different disciplines leading to increased efficiency and effectiveness of research	Increased farm production and incomes from research outputs
	One international/regional meeting on aspects of integrated gene management organized in CWANA	NARS and CG scientists	Scientific information on cereals and legumes exchanged and published	Enhanced knowledge and cooperation among NARS partners
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