Project 4: Food Legume Improvement

Rationale

In dry areas legume crops play an important role in food, feed and farming systems. A vast majority of people in the dry areas of South Asia, West Asia, Central Asia, China, North and East Africa, and Latin America are dependent on food legumes (lentil, chickpea, faba bean and grasspea) for their nutritional requirement and food security. The residues of food legumes are valuable animal feed. These legumes when grown in rotation with cereals provide sustainable cropping systems. The productivity of food legumes in developing countries remains stagnant and per capita availability is far below of the WHO recommended 45 g/person/day. Improvement in the production of these crops through germplasm enhancement and crop management will therefore contribute substantially to improved human nutrition in the developing world. Moreover, consumption of nutritionally enhanced pulses and low-neurotoxin grasspea will provide health security to the poorer section of society who cannot afford high-priced animal protein.

ICARDA's food legume research develops methodologies and technologies, improved genetic stocks and associated knowledge to improve crop productivity and eventually contribute to better livelihoods of people in the developing world. Legume research produces international public goods that are freely available to NARS. These include trait-based products (e.g. drought tolerant lentil and chickpea, Ascochyta blight and chocolate spot resistant faba bean, biofortified lentil), and the utilization of crop genetic resources. ICARDA has developed partnership with more than 50 NARS, CG-Centers, Advanced Research Institutions, regional organizations and NGOs. The project is fully engaged in the CGIAR Challenge Programs such as Generation and *Harvest Plus*. It is a part of CGIAR System Priority 2.

Food legume improvement links components of basic and strategic research with appropriate field evaluation across a diverse range of environments. The creation and application of linkages among gene identification, plant breeding, crop management practices, and livelihood outcomes across multiple sites and cropping systems are the guiding principles. The genetic enhancement research has focused its agenda for 2008-2010 to six products. These represent genetically enhanced, seed-embedded technologies developed by multidisciplinary teams (germplasm enhancement, integrated pest management, biotechnology, genetic resources) charged with the generation of products reflecting integrated solutions for target end users.

These products listed below form an exciting portfolio backed developed through consultation with and analysis of the needs of NARS.

- Stress tolerant (diseases, pests, drought and cold) cool-season legumes for food security, and crop intensification and diversification.
- Bio-fortified lentils (*Harvest Plus* Challenge Program) and low-toxin/toxin-free grasspea for improved nutrition and health.
- New traits through allele/gene mining for key traits (with the *Generation* Challenge Program).
- Improved methodologies and tools for genetic improvement (such as participatory plant breeding, pre-breeding, advanced biometry, international crop information system (ICIS), etc.).
- Integrated pest management (IPM) options for the control of diseases and insect pests.
- Capacity building in NARS programs.

Within ICARDA, it links with water and land management, crop/livestock production systems, assessment of poverty, adoption and impacts. MTP 2008-2010 on food legumes differs significantly from MTP 2007-2009 following a recent External Program and Management Review (EPMR) recommendation to merge research on food and forage/feed legumes Within forage/feed legumes there is a continued emphasis on grasspea but a reduced emphasis on the improvement of vetch forages for which the research bottleneck is not so much in the production of novel forage variants but rather their exploitation and the fitting of such types into the prevalent farming systems and different end-uses.

Project Outputs

The project goal, purpose, outputs, output targets and associated expected outcomes and impacts are provided in the attached Project Logframe. Where an Output Target contributes to a Challenge Program or a Systemwide/Ecoregional Program, this is indicated in the Project Logframe. Below, we describe for each Output: (a) the relation to system priority goals, (b) the impact pathway, (c) the research approach to developing international public goods (IPG), and (d) the role of partner organizations.

Output 1: Improved genetic stocks of food legumes (lentil, Kabuli chickpea and faba bean) developed through conventional, biotechnological and participatory approaches and methodologies and distributed to NARS globally through various means including International Nursery Network.

1.9 Relation to SP goals

The Output addresses SP 2A, 2B & 2C. Research related to SP 2A meets the general goal of sustainable production gains through genetic enhancement of lentil, Kabuli chickpea and faba bean to improve livelihoods and food security for the poor. It is closely related to SP 2B to meet the goal to enhance tolerance to drought, cold and heat to reduce production risk and improve yield stability. The output also contributes to SP 2C to achieve the specific goal of improving micronutrient contents in seed through breeding and use of biotechnological tools.

1.10 Description of Impact Pathways

Productivity of food legumes is severely constrained by various biotic and abiotic stresses. Among the constraints, drought is the most important and causes great losses and complete crop failures. Improved genetic stocks with resistances to various biotic and abiotic stresses identified at ICARDA are distributed to NARS. The NARS in the developing world use these sources of resistance in their breeding programs to produce resistant cultivars for the farmers.

Yield losses from different diseases and insect pests and have been estimated at millions of dollars. ICARDA uses pilot sites and Farmer Field Schools (FFS) to disseminate the knowledge and technology for pest control. Genetically-enhanced lentil, chickpea and faba bean varieties contribute millions of dollars to the poor in developing countries. The indirect benefit of growing legume varieties is their contribution to sustainable farming systems from nitrogen fixation. Improved varieties with increased biomass and crop residues as livestock feed does increase the productivity of crop-livestock system.

1.11 Research Approach to Develop International Public Goods

The major emphasis is on the identification of sources of resistance to various different biotic and abiotic stresses, identification of germplasm with different desirable agronomic and quality traits and then recombining them. The cooperative research to combine these traits through breeding results in the development of elite lines with adaptation to targeted environments, the generation of new technologies or research methodologies, and/or new information of value across many countries. These outputs, which result from joint efforts with NARS, advanced research institutions, governmental and non-governmental organization, are freely exchanged among partners and end-users and are clearly International Public Goods. For instance, effective resistance sources are published and germplasm made available to NARS and ICARDA breeders. All pest management packages developed are distributed to NARS research groups and extension, and to farmers' groups, and these are applied in many countries.

1.12 Partners' Roles

CGIAR Centers: **ICRISAT** generates data on fusarium wilt in chickpea for sharing with ICARDA scientists

CGIAR Challenge Programs:

Water and Food: provides resources to conduct research and improvement in lentil and chickpea in Eritrea.

HarvestPlus: provides funding to breed biofortified lentils. CIAT and IFPRI provide the leadership to assemble scientists from many countries who share technical know-how and methodologies.

Generation CP: provides funding to characterize molecular diversity in lentil, faba bean and chickpea with ICRISAT.

International partners:

Australia:

- **University of Adelaide and South Australian Research and Development Industry (SARDI)**: collaboration in the management of food legume diseases and analyses of micronutrients in lentil.
- **Centre for Legumes in Mediterranean Agriculture (CLIMA)** and Department of Agriculture, Western Australia: In integrated disease management in food legumes and Collaboration to widen the genetic base of lentil in India, Nepal and Bangladesh.
- **Department of Primary Industries NSW**: in management of food legume fungal and viral diseases.
- **Department of Primary Industries (DPI), Horsham,** Victoria: development of elite genetic stocks, joint disease screening management and molecular characterization of food legume fungal and virus diseases.

Canada: Crop Development Center, University of Saskatchewan, Saskatoon: Collaboration in morphological and molecular characterization of drought tolerance in chickpea through a Ph.D. student; chickpea materials for resistance to Ascochyta blight are developed both at ICARDA and CDC Saskatoon and evaluated at ICARDA. Sources of resistance to Stemphylium blight and its inheritance, and resistance to Anthracnose and Ascochyta blight in lentil in cultigens and wild relatives.

USA: Washington State University, Pullman: Winter-hardy lentil developed at ICARDA and Washington State University is evaluated in Turkey for high altitude areas. Inheritance and molecular markers for rust and Stemphylium blight diseases is underway through a Ph.D. student. Additionally breeding of chickpea for Ascochyta blight resistance in Mediterranean environments is done with Washington State University.

NARS Partners:

Egypt and Tunisia: Fusarium wilt resistance screening in chickpea
Ethiopia: Rust screening in lentil
Bangladesh and India: Rust and Stemphylium blight screening
Australia and Pakistan: Ascochyta blight in lentil
Egypt, Tunisia and Morocco: Chocolate spot and Orobanche in faba bean
Iran: Drought and cold tolerance in chickpea and lentil
Turkey: Cold tolerance in chickpea and lentil

<u>Output 2</u>: Improved genetic stocks of grasspea with low-toxin and higher biomass yield developed through conventional and biotechnological methods, and distributed to NARS.

2.1 Relation to SP Goals

The output delivers low-toxin grasspea cultivars for food safety. Consumption of low-toxin grasspea by rural poor will reduce health hazards, thus linked with SP 2C. It meets the specific goal 2, a bio-fortification strategy through genetic detoxification of the diets of nutritionally disadvantaged populations, who rely on grasspea seed for food security.

2.2 Description of Impact Pathways

Grasspea is grown and consumed in South Asia (Bangladesh, India, Pakistan, and Nepal), East Africa (Ethiopia, Eritrea) and in certain areas of China. Due to its drought tolerance, grasspea is the only option as a staple food for the poor in drought-prone environments. But its over consumption creates a neurological disorder called neuro-lathyrism, resulting in disability to the poor people in these areas. As its cost of production is very low and the crop gives good remuneration to farmers in the form of seed, fodder and residues, farmers in these countries grow the crop. Improved grasspea cultivars with low neurotoxin (β-ODAP) content and higher biomass yield will provide nutritional and health security, and reduce health hazards to these consumers. The ultimate beneficiaries of low-toxin varieties are resource-poor farmers and consumers who cannot afford animal products.

2.3 Research Approach to Develop International Public Goods

Major emphasis is on identification of low-ODAP grasspea lines/cultivars with high biomass to meet both food and feed requirements. New genetic stocks, technologies or research methodologies and new information are useful over many countries. These outputs, which are the outcomes from research in

collaboration with NARS, advanced research institutions, governmental and non-governmental organization, are freely exchanged among the partners and end-users with the scientific results published in international journals.

2.4 Partners' Role

Australia: CLIMA is facilitating the anti-nutritional analysis in grasspea
Belgium: Gent University collaborates in the ODAP analysis
Ethiopia, Bangladesh, Nepal, China, Pakistan and India: Field testing of low-ODAP grasspea lines

<u>Output 3</u>: Enhanced research capacity of NARS scientists through training, visits, workshops and conferences.

3.1 Relation to SP Goals

Enhanced capacity of NARS scientists in research and technology generation will lead to delivery of the above outputs efficiently, which will indirectly contribute to meet SP 2A, 2B and 2C.

3.2 Description of Impact Pathways

The project influences human capacity in disciplines of genetic resources, integrated pest management, breeding and genetics, biotechnology, biometry and seed systems. Many NARS researchers/technicians visit the Center's laboratories and fields to become acquainted with techniques and methodologies. In the degree program the graduate students not only contribute to ICARDA's research, but also become the future leaders of NARS research systems. Trained people assist in moving research knowledge and practices toward the ultimate beneficiaries - the farmers of dry areas.

3.3 Research Approach to Develop International Public Goods

Students' thesis research and joint research with NARS partners is published in international scientific journals and other media and is available to all as IPGs.

3.4 Partner's Role

The following Universities and advanced NARS are collaborating in capacity building.

Aleppo University, Syria: Research on cold, heat and salinity tolerance.

University of Saskatchewan, Canada: Genetics of Stemphylium blight resistance and identification of sources of resistance to Anthracnose, Ascochyta blight in lentil. Drought tolerance in chickpea

Washington State University, USA: Inheritance and marker identification for lentil rust and Stemphylium blight resistance in lentil

Bangladesh Agricultural University, Bangladesh: Studies in lentil diversity using morphological and molecular means

Rajshahi University, Bangladesh: Relay cropping and seed priming with diverse lentil genotypes in Bangladesh.

Alemaya University, Ethiopia: Studies for drought tolerance in Ethiopian lentil landraces

Georgian Agrarian University, Georgia: Genetic diversity in Mediterranean lentils

Project 4	**Food Legume Improvement**
Goal	Sustainable conservation and use of the biodiversity of food legumes to increase agricultural production in the non-tropical dry areas
Purpose	Improved livelihoods of resource-poor farmers from the conservation, improvement and sustainable use of food legumes and the adoption of improved varieties and associated technologies.

Output Targets		Intended Users	Outcomes	Impact
Output 1: Improved genetic stocks of lentil, kabuli chickpea and faba bean developed through conventional, biotechnological and participatory methodologies and distributed to NARS globally through various means including international nursery network				
2008	Advanced lines and superior germplasm of lentils, kabuli chickpea and faba bean with multiple disease resistance, cold and drought tolerance, improved nutritive value (high Fe and Zn in lentil) and high yield potential developed and distributed to NARS	ICARDA and NARS breeders; farmers; consumers	Increased availability of improved genetic material of chickpea, lentil and faba bean Genetic stocks with biotic and abiotic stress resistance combined with good agronomic background and better nutritional quality available	Genetic vulnerability and risk from pests and diseases reduced in farmers' fields Resource-poor farmers less vulnerable to abiotic and biotic stresses Improved farm production and livelihoods of rural people Alleviation of malnutrition among the poor in developing countries through providing health and nutritional security
	Molecular markers identified for Ascochyta blight in chickpea	ICARDA breeders and biotechnologists	Genetics of Ascochyta blight resistance elucidated, genes identified and mapped, and MAS used in screening for resistance in chickpea	Reduced crop losses and sustainable increases in crop production and farm incomes
	Sources of resistance in wild relatives, landraces and breeding lines for viruses, fungal pathogens and insect pests identified. Pathogenic variability of *Ascochyta rabiei* and *Ascochyta fabae* characterized.	ICARDA, international and NARS breeding programs	Broader gene pool for resistance to biotic stresses available to breeding programs for germplasm improvement	Reduced crop losses and sustainable increases in crop production and farm incomes
2009	Improved genetic stocks of chickpea, lentil and faba bean with combined resistance to abiotic and biotic stresses developed and distributed to NARS	International and NARS breeding programs	Increased availability of improved genetic material of chickpea, lentil and faba bean	Genetic vulnerability and risk from pests and diseases reduced in farmers' fields

Output Targets		Intended Users	Outcomes	Impact
	Molecular markers identified for rust resistance in lentil and drought tolerance in chickpea.	ICARDA biotechnologists and breeders, advanced NARS and ARIs	Genetic stocks developed with alternative biotic and abiotic stress resistance	Reduced crop losses and sustainable increases in crop production and farm incomes
	Integrated Pest management components of Orobanche infestation in faba bean validated.	International and NARS plant protection specialists	IPM options developed for use by farmers	Reduced crop losses and sustainable increases in crop production and farm incomes
2010	Improved genetic stocks/populations of chickpea, lentil and faba bean with combined resistance , enhanced nutritional quality (high Fe, Zn and B-Carotene) in lentil), added-value traits and higher yield delivered to national programs through international nursery network	NARS plant breeders; farmers; consumers	Genetic stocks with biotic and abiotic stress resistance, enriched nutritional quality combined with good agronomic background available	Improved farm production and livelihoods, enhanced nutrition for rural people
	QTLs for drought tolerance identified in chickpea and lentil.	ICARDA breeder and biotechnologist, advanced NARS and ARIs	Efficient selection and fast track of improved genetic stocks with drought tolerance (chickpea and lentil) Novel sources of biotic and abiotic stress resistance developed	Reduced crop losses and sustainable increases in crop production and farm incomes
	Identified sources of resistance genes in wild relatives, landraces and breeding lines of legumes for diseases and insect pests introgressed into elite cultigens.	International and NARS breeding programs	Cultigens used in breeding programs	Reduced crop losses and sustainable increases in crop production and farm incomes
Output 2. Improved genetic stocks of grasspea with low-toxin and higher biomass developed through conventional and biotechnological methods and distributed to NARS.				
2008	Available germplasm evaluated for ODAP (ß-N-Oxalyl-a- ß diaminopropionic acid) content and seed increase.	ICARDA and NARS breeders	Low-ODAP lines identified	Improved health with reduced risk of neuro-lathyrism
2009	Grasspea lines evaluated for high biomass for feed	Farmers	High biomass lines identified	Increased farm income and reduced risk in drought prone areas
2010	F3 segregating materials developed and distributed to NARS	NARS breeders	Identification of lines with low-ODAP and high biomass	Reduced health hazard and generation of higher income
Output 3. Enhanced research capacity of NARS scientists through training, visits, workshops and conferences.				
2008	Training course in food legume improvement Five MS/PhD students' research co-supervised by ICARDA Food legume travelling workshop organized in three countries	NARS scientists, technicians	Increased capacity of NARS scientists/technicians leading to enhanced efficiency and effectiveness	Trained NARS scientists with improved research capacity

Output Targets		Intended Users	Outcomes	Impact
2009	Training for 15 NARS researchers Regional training course on plant breeding and biometry in Central Asia and the Caucasus	NARS researchers	Increased availability of specialists in different disciplines. Improved knowledge and skills in respective field of research	Trained NARS scientists with improved research capacity
2010	Training for 18 NARS researchers Regional course on legume breeding and biometry in South Asia	NARS scientists/specialists	Increased capacity of NARS scientists	Trained NARS scientists with improved research capacity