ANNUAL REPORT 2007

ICARDA

International Center for Agricultural Research in the Dry Areas

About ICARDA and the CGIAR

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is one of 15 centers supported by the CGIAR. ICARDA's mission is to improve the welfare of poor people through research and training in dry areas of the developing world, by increasing the production, productivity and nutritional quality of food, while preserving and enhancing the natural resource base.

ICARDA serves the entire developing world for the improvement of lentil, barley and faba bean; all dry-area developing countries for the improvement of on-farm water use efficiency, rangeland and small-ruminant production; and the Central and West Asia and North Africa (CWANA) region for the improvement of bread and durum wheats, chickpea, pasture and forage legumes, and farming systems.

ICARDA's research provides global benefits of poverty alleviation through productivity improvements integrated with sustainable natural-resource management practices. ICARDA meets this challenge through research, training, and dissemination of information in partnership with the national, regional and international agricultural research and development systems.

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

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

ANNUAL REPORT 2007

ICARDA

International Center for Agricultural Research in the Dry Areas

Citation:
ICARDA. 2008. ICARDA Annual Report 2007. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria. iv + 64 pp.

ISSN: 0254-8316

AGROVOC descriptors: *Cicer arietinum; Lens culinaris; Vicia faba; Hordeum vulgare; Triticum aestivum; Triticum durum; Lathyrus sativus; Aegilops; Medicago sativa; Pisum sativum; Trifolium; Trigonella; Vicia narbonensis;* feed legumes; shrubs; fruit trees; goats; ruminants; sheep; livestock; agricultural development; dryland farming; farming systems; animal production; crop production; agronomic characters; biodiversity; biological control; disease control; pest control; pest resistance; drought resistance; genetic maps; genetic markers; genetic resistance; genetic resources; genetic variation; land races; germplasm conservation; plant collections; microsatellites; land use; pastures; grassland management; steppes; rangelands; reclamation; environmental degradation; irrigation; water harvesting; water management; harvesting; rural communities; rural development; training; human resources; development; malnutrition; nutritive quality; poverty; mechanical methods; remote sensing; research networks; research; resource conservation; resource management; seed production; stubble cleaning; Sunn pest; sustainability; temperature resistance; cold; vegetation; geographical information system; diffusion of information; agroclimatic zones; arid zones; semi-arid zones; international cooperation; Middle East; North Africa; West Asia; Central Asia and the Caucasus.

AGRIS category codes: A50, A01, E10, F01, F30, H10, H20, H60, L01, U30

CONTENTS

FOREWORD

In 2007, ICARDA celebrated its thirtieth anniversary. The Center and its partners have worked together for three decades to improve the food security and livelihoods of the poor in dry and marginal areas. During this time, we have seen significant changes in the biophysical environment and in socio-economic circumstances. New farming technologies, new livelihood options, and better policies and institutions are speeding up agricultural development in the world's dry areas, and we are proud of the role we have played in this progress. During ICARDA's Presentation Day held in May 2007, the Center's achievements over the last 30 years were presented to ICARDA's partners – national research and academic institutions, donors, farmer groups, civil society organizations and others.

ICARDA's mandate is as relevant today as it was when the Center was established in 1977. The Center's core mission – research for agricultural development – remains unchanged, but the research agenda has evolved in response to new challenges and changed circumstances. The aim has been, and still is, to conduct demand-driven research, to solve those problems that our clients consider important. So, as ICARDA begins its fourth decade, we are increasingly focusing on the pressing challenges of climate change, desertification and rising food prices.

ICARDA's new Strategic Plan for 2007-2016 sets the direction for our response to these challenges. The new plan emphasizes continuity within change: building on our experience in the Central Asia and West Africa (CWANA) region, and widening our scope to include dry areas globally. The plan envisages that we and our partners will be actively involved at every stage in the research-development continuum – strategic research, adaptive research, technology transfer, and impact monitoring.

We thank all our partners for committing so much time and energy in helping us develop the new Strategic Plan. We commend staff, too, at all levels, for their commitment and hard work. We are also grateful to the members of the two external review panels (External Program and Management Review, and Center-Commissioned External Review on Management and Finance) for their inputs into the process. ICARDA's program structure has been streamlined, and we have recruited top-notch staff to strengthen research in specific areas and to reinforce our management team.

Successful research-for-development depends on collaboration with all stakeholders, particularly with national agricultural research systems. During 2007 we broadened our already extensive network of partnerships, and strengthened ties with a number of advanced research institutions. For example, agreements signed with institutions in Australia, Germany, Japan and Spain will improve our strategic research as well as our capacity development programs. New agreements with developing-country governments have broadened the reach and the impact of our work at the farm level. We greatly value our relationships with national research systems, as they are an endorsement of our scientific reputation and our commitment to national agricultural development.

New strategic research partnerships entered into in 2007 reflect ICARDA's increasingly global thrust. The Global Rust Initiative, led jointly by ICARDA and CIMMYT, aims to combat a new race of wheat stem rust disease that has already spread from East Africa into West Asia, and now threatens wheat production in other parts of Asia, the Mediterranean, and even the Americas. ICARDA is a partner in another initiative: the Global Crop Diversity Trust genebank in Svalbard, Norway, which will hold the world's largest collection of seeds, and play a key role in conserving global crop genetic diversity.

ICARDA will continue to strengthen its research and capacity development programs, to help farmers in dry areas cope with climate change. Our integrated approach combines adaptation, mitigation and ecosystem resilience. Improved crop varieties hold the key to adapting to climate change, improving food security and arresting the upward spiral of food prices. During the year, as many as 26 new varieties, developed from ICARDA germplasm, jointly by the Center and national research programs, were released in 12 countries. They include varieties of wheat, barley, lentil, chickpea and forage legumes, with various trait combinations, such as high yield, drought/cold tolerance, disease resistance, and suitability for mechanized production.

There were many other highlights. For example, ICARDA scientists have developed new, rapid, low-cost techniques, using GIS tools, to map agro-ecological zones for better research targeting in large and complex ecosystems. They have identified new biological control agents – using insect-killing fungi – and developed methods to protect wheat crops from the Sunn pest that reduce both pesticide use and production costs. Our biotechnologists are developing a new, robust approach to identify plant genes that confer resistance to drought and other environmental stresses. Farmer-participatory breeding, pioneered in the CWANA region by ICARDA, continues to spread to new countries, empowering resource-poor communities in remote areas. Improved food legume genotypes have been developed with better nutritional quality (e.g. low levels of tannin, high content of micronutrients). Improved techniques for land and water management are helping to increase water productivity, make better use of scarce water resources, and even to rehabilitate degraded rangeland areas. Protected agriculture techniques are being introduced in Afghanistan, Yemen and the Arabian Peninsula, helping to conserve resources and improve farmers' incomes.

Guided by the new Strategic Plan, the Center will now move forward, revitalized and equipped with advanced science and innovative ideas, to continue delivering world-class research products and international public goods to improve the livelihoods of poor farmers in non-tropical dryland areas worldwide.

Guido Gryseels
Chair, Board of Trustees

Mahmoud Solh
Director General

Highlights of the Year

In 2007, ICARDA celebrated its 30th anniversary. We embarked on our fourth decade with renewed commitment to contributing to global development and improving the lives of the poor, through our research and the international public goods we create and share with the world.

During the year, we forged ahead on the priorities set in our renewed, refocused Strategic Plan 2007–2016, particularly on the challenges of raising crop productivity to combat increasing food prices, and developing options for poor farmers to cope with climate change, land degradation and desertification. This progress builds on decades of fruitful partnerships in research for development. The many honors awarded to ICARDA staff during the year show how highly our partners and peers regard our work.

ICARDA's 30th Anniversary: Reflecting on the Past, Facing the Future

ICARDA celebrated its 30th anniversary in May 2007, taking the opportunity to reflect on both the past and the challenges ahead. Guests from 20 countries – ministers, representatives of NARS, partner organizations, donor agencies, diplomats, former Directors General and Board Members, among others – shared the celebrations, demonstrating the breadth and depth of partnerships and support for ICARDA's work.

H.E. Prof. Dr Adel Safar, Syrian Minister of Agriculture and Agrarian Reform, delivered a message of congratulation from H.E. Eng. Mohamed Naji Otri, Prime Minister of Syria. Dr Guido Gryseels, Chairperson of ICARDA's Board of Trustees, and Dr Mahmoud Solh, Director General, welcomed the guests. The celebrations included the presentation of Staff of the Year Awards, a scientific symposium, a tour of ICARDA's research and field facilities, and a traditional barbecue.

Dr Mahmoud Solh, ICARDA Director General (left), and Dr Guido Gryseels (right), Chair of ICARDA's Board of Trustees, reflected on past achievements and future challenges, during the 30th anniversary celebrations.

"In particular, we recognize this [ICARDA's work] is honest support, implemented through genuine partnerships and provided in response to national and regional needs."
H.E. Eng. Mohamed Naji Otri, Prime Minister of Syria

The guests at the 30th anniversary event included ministers, leaders from national agricultural systems, scientists and national policy makers, plus representatives of partner organizations, donor agencies and diplomatic corps, as well as ICARDA pioneers and the media.

ICARDA's publications captured the interest of many guests at the 30th anniversary celebration, and provided further details of the Center's achievements.

"… this is an opportune moment to pause, and to reflect on what we have achieved … Together, we have made enormous impacts on the lives of the poor, and built strong and lasting partnerships for research and development."
Dr Guido Gryseels, Chair, ICARDA Board of Trustees, at ICARDA's 30th anniversary celebrations

Improved varieties released in 2007

Barley	Bakharli Zhibek zholy Sana (Sonata-8)	Azerbaijan Kazakhstan Turkmenistan
Chickpea	CDC Luna Zumrad Djahangir Janallik	Canada Uzbekistan Uzbekistan Kazakhstan
Forage	Azzahra (IG# 123064) Oudaya (IG# 51511)	Morocco Morocco
Lentil	Arzu Angoori Ibla 1 Oltin Don Dormon	Azerbaijan India Syria Uzbekistan Uzbekistan
Spring Bread Wheat	Barkume Douma-4 (ACSAD 901) Nabeta (Kauz"S") Bohouth 8 (Douma 19918) Golan-2	Ethiopia Syria Sudan Syria Syria
Triticale	Farhad Norman	Uzbekistan Uzbekistan
Winter and Facultative Wheat	Hanli Beskopru Alex Norman Egemen	Turkey Turkey Tajikistan Tajikistan Kazakhstan

More Productive Varieties Released in 2007

Crop varieties that produce more and are resistant to diseases, pests and the vagaries of weather help farmers get more from their land and are critical in the fight against rising food prices and food scarcity. Working with our national partners to deliver better varieties that meet their needs is at the heart of ICARDA's work. In the 30 years since ICARDA was founded, over 850 improved varieties have been developed and released in more than 40 countries. In 2007 alone, 26 improved varieties were released in 12 countries (see table).

Exploiting New Science: Biotechnology and Biosafety for Agriculture and the Environment

Biotechnology has the potential to produce more food sustainably to meet growing global food needs, but the food must be nutritionally and environmentally safe. The commercialization of transgenic crops in West Asia and North Africa is hampered by the lack of common biosafety regulations.

A clear regulatory framework will help increase the benefits from biotechnology and address biosafety concerns. Major stakeholders from 16 countries and three international organizations met to discuss such an integrated framework on biotechnology and biosafety for the WANA region at a workshop at ICARDA headquarters in September, co-sponsored by FAO, UNEP and ICARDA.

This meeting was the first to involve such a wide range of organizations and ministries of agriculture and the environment. As a result, a regional project to enhance capacity in biotechnology and biosafety, and to harmonize biosafety regulations across West Asia and North Africa, is on the cards.

A Regional Consultation on Biotechnology and Biosafety for Agriculture and Environment was held at ICARDA in September. Dr Mahmoud Solh, Director General, ICARDA (second from right) inaugurated the consultation. Seated from left to right are Dr Alex Owusu-Biney, Regional Coordinator for Africa, Biosafety Division of GEF, UNEP; Dr Fee Chon Chong, Manager of UNEP/GEF Projects on the Implementation of National Biosafety Frameworks; and Dr Kakoli Ghosh of the UN Food and Agriculture Organization.

Global Conservation Strategy for Legume Crops

Conservation of genetic resources of important crops is critical. Plant breeders draw on conserved genetic resources to develop better varieties to boost food production and, ultimately, to improve the lives of resource-poor people globally.

In February 2007, ICARDA hosted a meeting to develop a global collaborative strategy for ex situ conservation of food legume genetic resources – the *Global Conservation Strategy Meeting for Chickpea, Lentil, Faba Bean, and Grass Pea*. The four legumes are the main sources of protein for nearly 2 billion people. The meeting was organized by ICARDA's Genetic Resources Unit and sponsored by the Global Crop Diversity Trust.

The 36 participants from 17 countries, representing genebanks, national research centers, government agencies, policy makers, Bioversity International, ICARDA, ICRISAT, and the Trust, developed a clear strategy for conservation of food legume genetic resources and set out the next steps in developing and implementing a formal collaborative strategy.

The 'Global Conservation Strategy Meeting for Chickpea, Lentil, Faba Bean, and Grass Pea', held at ICARDA, 19-22 February, brought together experts in conserving valuable genetic resources. Front row: Dr Majd Jamal (second left), Director General, General Commission for Scientific Agricultural Research, Syria; Dr Geoffrey Hawtin (fourth left), Senior Advisor, Global Crop Diversity Trust; Dr Mahmoud Solh (center), Director General, ICARDA; Dr Cary Fowler (third right), Executive Director, Global Crop Diversity Trust; and Dr Bonnie Furman (fourth right), Interim Head, ICARDA Genetic Resources Unit.

Harmonization of Seed Regulations

Harmonization of seed policies and regulations is a key issue for the Economic Cooperation Organization (ECO) countries: Afghanistan, Azerbaijan, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkey, Turkmenistan, and Uzbekistan. Harmonization will boost trade in seed, give farmers a wider choice, and encourage the private sector to invest in the seed industry.

ICARDA and ECO NARS are partners in a program 'Strengthening Seed Supply in the ECO Region'. This program, funded jointly by FAO and ECO countries, looks at issues such as seed production, distribution and marketing, private investment, seed certification, quarantine procedures, seed trade, and setting up seed associations.

The first of a series of workshops in the program was hosted by the Federal Seed Certification and Registration Department in Islamabad, Pakistan, in January 2007. The workshop explored ways of harmonizing the release of new varieties and plant quarantine/phytosanitary measures.

The outcome of the workshop was a commitment to draft a regional plan that will be circulated to member countries in both English and Russian for comment prior to a second round of consultation meetings. Once refined and adopted, the regional plan will be presented to the ECO ministerial meeting for endorsement.

Promoting International Seed Trade

The Central and West Asia and North Africa (CWANA) region imports seeds worth over US$250 million. Low costs and favorable environments for production give the private seed sector in the region a comparative advantage in this significant market. To boost seed trading in the region, the Egyptian Seed Association, in collaboration with ICARDA's Seed Unit and the Turkish Seed Industry Association, under the auspices of the National Seed Council of Egypt, organized the Second International Seed Trade Conference in Giza, Egypt, in November 2007.

Over 550 participants, from 23 countries and a very diverse range of organizations, made it one of the most successful seed trade conferences in the region. The delegates represented private and public seed companies from the CWANA region, agricultural suppliers from Africa, Asia, Europe and USA, seed equipment manufacturers from Asia, Europe and USA, international, regional and national seed trade associations from Asia and Europe, and international and regional research and development organizations working on seed (FAO, ISF, ISTA, OECD, UPOV, CIHEAM, and ICARDA).

The success of the First and Second International Seed Trade Conferences for CWANA has already led to plans for a CAC Seed Trade Conference to be held in June 2008 in Bishkek, Kyrgyzstan, and plans for a Central and West Asia Seed Trade Association.

Early Warning System for Wheat Stem Rust

An early warning system for outbreaks of the deadly stem rust of wheat would allow preventative action to be taken quickly and check the disease's spread to other parts of the world. Scientists and researchers from ICARDA, CIMMYT, FAO, and research organizations from Australia, Canada, Egypt, Ethiopia, Kenya, the USA and Yemen met at ILRI in Addis Ababa, Ethiopia, in October 2007 to put together a strategy for developing such an early warning system.

Monitoring and forecasting systems for stem rust, particularly the new and highly virulent race Ug99, could rapidly pinpoint

ICARDA's Dr Amor Yahyoui (second from left) discusses ways to fight the spread of stem rust disease with local and international scientists at Kulumsa Agricultural Research Station, Ethiopia. A new, virulent race of the stem rust fungus is threatening wheat supplies across large tracts of the world's wheat-growing areas.

the location of outbreaks and help predict more accurately where the stem rust might appear. Such systems, using geographic information systems and crop and weather data, are already being used to forecast plagues of locusts.

European Parliament Delegation Visits ICARDA

The European Commission is ICARDA's third largest donor and takes a keen interest in the Center's genebank and research, especially in biotechnology. In September, ICARDA welcomed a delegation of the European Parliament, led by Mr John Purvis, CBE, Member of the European Parliament for Scotland. The visitors were thoroughly briefed on the relevance of ICARDA's work to development and improving the lives of the poor, and complimented us on our achievements.

Helping Farmers Adapt to Climate Change

Adaptation, Mitigation, and Ecosystem Resilience

The impact of climate change will be felt around the world – and nowhere more so than in dry areas, where ICARDA's work is focused. ICARDA, with its partners, has developed a wide range of technologies that will reduce the impact of climate change on smallholder farming communities. These include varieties with greater heat and drought tolerance, resistance to diseases and pests, and adaptation to marginal environments.

Climate change is a priority area in ICARDA's Strategic Plan for 2007–2016. Our approach combines three aspects: adaptation, mitigation and ecosystem resilience. The aim is to help small-scale farmers maintain productivity and food security under conditions of greater variability, larger temperature extremes, and more intense extreme events.

The research agenda includes, for example:

- Crop improvement and exploitation of genetic diversity for adaptation to climatic stress and variability; prospecting for adaptation genes
- Physiology studies to understand adaptation mechanisms in plants and animals
- Collection and use of commercially promising or under-utilized plants
- Understanding the dynamics of pests and diseases under a changing climate
- Policy and socio-economic aspects of water management, e.g. co-management by the community
- The role of livestock and rangelands in buffering climate change
- Diversification of livelihoods, including new crop–livestock options
- Conservation agriculture, e.g. crop rotations that reduce energy consumption and increase carbon sequestration
- Improved water-use efficiency and water allocation
- Land management, soil fertility
- Studying local coping strategies, and drawing out lessons for application to other areas
- Trade-offs between development and climate change. For example, will policy reform on water (in order to improve overall productivity) reduce water access for the poor?
- Identifying hot spots: where will climate change affect food security, poverty and environmental sustainability most severely?

Climate Change Strategies for Africa and the Mediterranean

Climate change will have far-reaching effects in Africa and the Mediterranean. Acknowledging this, the *International Solidarity Conference on Climate Change Strategies for African and Mediterranean Regions*, held in Tunis, Tunisia, in November, looked at climate change from a range of perspectives such as energy, infrastructure, natural resources, agriculture and the environment, partnerships, solidarity and funding.

An initiative of the Tunisian Government, the meeting sought to get stakeholders with different perspectives to think about

Afghanistan: on-farm trials of new wheat varieties that could help maintain food production in a changed climate how to deal with the impacts of climate change, and how measures to combat climate change might be funded. There were 1400 participants, including ministers from Africa and the Mediterranean region, climate change experts, and representatives of international and regional organizations, donors, multilateral institutions, the private sector and civil society organizations. ICARDA helped organize the meeting. And, in its addresses, presentations and publications distributed at the meeting, highlighted technologies, tools and research findings that will help integrate measures to combat climate change into development strategies.

Critically, the meeting achieved agreement on the regional input to the Bali Kyoto Protocol meeting in December 2007. As a next step, an Integrated Climate Change Strategy for Africa and the Mediterranean will be developed.

Partnerships

ICARDA's leaders devote a great deal of thought, time and energy to nurturing and expanding partnerships, cooperation and collaboration. ICARDA's research is led by its clients' needs. This means finding out what partners want and the areas where collaboration with ICARDA can make the greatest impact. During 2007, the Director General and ICARDA teams visited Egypt, Ethiopia, FAO, Germany, IFAD, Qatar and Sudan, and received visitors from the EU, Libya and Tunisia. These meetings helped us learn more about our partners and helped our partners better understand ICARDA's work.

Sudan and ICARDA will be collaborating more closely on rainfed farming, after a new ICARDA office opened in Khartoum in 2007. Pictured here at a reception are Sudan's Minister of Science and Technology, H.E. Abdelrahman Saeed (fourth right), flanked by Dr Mahmoud Solh, Director General, ICARDA and Dr Khaled Makkouk, Regional Coordinator of ICARDA's Nile Valley and Sub-Saharan Africa Regional Program; Dr Azhari Hamada (second left) is the Director General of Sudan's Agricultural Research Corporation.

To strengthen ICARDA's collaboration with NARS in Sub-Saharan Africa, the Director General visited Sudan and Ethiopia in April 2007. Collaboration in Sudan will focus on Sudan's rainfed regions, developing joint FAO–ICARDA projects to serve these regions, and on graduate studies for national scientists. ICARDA ties with Sudan were strengthened by the opening during the year of an office in Khartoum. In Ethiopia, collaboration will be in natural resources management, small ruminants, integrated pest management in horticulture, capacity building, and the Borlaug Global Rust Initiative, especially in screening wheat for resistance to stem rust.

In Egypt, the Director General met with the Minister of Agriculture and Land Reclamation to further strengthen collaboration between ICARDA and Egypt.

In Yemen, an ICARDA team reviewed existing projects, such as the IFAD-funded project to disseminate research findings, and possibilities for future projects, for example in cooperation with USAID.

A delegation from Germany visited ICARDA in April to explore areas in which the Center could work with German partner institutions, or provide technical inputs to German-funded development projects in the dry areas. This visit was followed up by a visit by an ICARDA team to Germany in June to take part in the Desertification and Security Conference, and meet with GTZ, ZALF, the Dryland Research Center (Hamburg University), the Center for Development Research (ZEF), and the University of Bonn.

During these visits, ICARDA emphasized that technological changes in agriculture can improve sustainable livelihoods, and reduce armed conflict and extremism by improving nutrition, reducing poverty and helping to manage natural resources sustainably. In the discussions, many possible areas for collaboration emerged, such as linking ICARDA's GIS Unit with ZALF to model cropping systems. Other possibilities included inviting MSc students studying International Agriculture at the Dryland Research Center to do their research projects at ICARDA; collaboration between the Centre for Development Research (ZEF), University of Bonn, on a project in Uzbekistan on livelihoods; and land and water management and applied research inputs to GTZ projects in Afghanistan, Sudan, and Central Asia and the Caucasus.

During the year, the Director General also met key donor representatives and partners to help focus ICARDA's research as clearly as possible on development issues. At FAO, discussions were on the joint efforts by FAO and the CGIAR centers in capacity building and how to speed up the implementation of

"None of this would have been possible without the active participation and support of our partners … From the beginning, ICARDA recognized that its strength lies in partnerships, and sharing resources, expertise and information with NARS."
Dr Mahmoud Solh, ICARDA Director General, at the Center's 30th anniversary celebrations

the treaty on plant genetic resources. Other issues covered were the International Barley Genetics Symposium, the Borlaug Global Rust Initiative and an Expert Consultation on strategic research on small ruminants and horticulture.

At IFAD, climate change and how ICARDA's work can help the resource-poor adapt, rebuilding agricultural research in Iraq, the Arabian Peninsula Regional Program, the Oasis Challenge Program, and high-value crops and value-added products were discussed. IFAD was particularly interested in how ICARDA's work feeds into development.

Honors and Awards

ICARDA scientists received many prestigious awards in 2007, testimony to the Center's world-class science and significant contribution to development.

Director General Dr Mahmoud Solh was awarded an honorary doctorate by the Tajik Agrarian University, Dushanbe. The award was made in recognition of Dr Solh's long-standing contributions to agricultural science, to partnership building in Tajikistan, and to developing national research capacities throughout the CAC region.

The National Academy of Agricultural Sciences (NAAS), a leading think-tank in India, elected Dr William Erskine as a Fellow.

The Turkish Chamber of Agricultural Engineers awarded Dr Mustapha Pala, Senior Agronomist, their Science Award for 2007 for his research to improve sustainable agriculture in dry areas and its applicability to Turkish agriculture.

The Pakistan Council for Science and Technology presented Dr Manzoor Qadir, Marginal Water Quality Management Specialist, with the Research Productivity Award, in recognition of his work on management of marginal-quality water resources and salt-affected soils.

The Soil and Plant Analysis Council, USA, presented Dr John Ryan, Soil Scientist, the J. Benton Jones Award for 2007. Dr Ryan is the first CGIAR scientist to win this prestigious award given once every two years for outstanding contributions in soil and plant analysis. In further recognition of his lifelong contribution to soil science, Dr Ryan was presented with the 2007 Soil Science Distinguished Service Award by the Tri-Society (American Society of Agronomy, Soil Science Society of America, and Crop Science Society of America).

Dr R.S. Malhotra, Senior Chickpea Breeder, was presented with honorary doctorates in recognition of his outstanding contributions to food legume research by the Shimkent University, Kazakhstan and the Gulistan State University of Uzbekistan. The Scientific Production Center of Farming and Plant Growing (SPCFPG), Almaty, also presented him with a Letter of Gratitude for his active support in "broadening the genetic base, and development of breeding work on leguminous crops for the Kazakhstan Republic".

Dr Mustapha El Bouhssini (right) receiving the International Plant Protection Award of Distinction from Dr Hans Herren, World Food Prize Laureate and President of the International Association for the Plant Protection Sciences

The French government presented Dr Henri Carsalade, Member of ICARDA's Board of Trustees, with the Officier de la Légion d'Honneur Medal in recognition of his international public service.

The Government of Bangladesh honored Dr Ashutosh Sarker, Lentil Breeder, for his significant contributions to the nutritional security of the resource-poor in Bangladesh through lentil improvement.

ICRISAT presented Dr Raj Paroda, ADG (International Cooperation), with the Outstanding Research Partner award on its 35th anniversary and named ICRISAT's genebank the R.S. Paroda Genebank, in recognition of his contribution to the Center's development.

The International Association for the Plant Protection Sciences presented Dr Mustapha El Bouhssini, Senior Entomologist, with the International Plant Protection Award of Distinction for his contributions to the development of integrated pest management in cereals and legumes in Central and West Asia, and North Africa.

The Jordanian government honored Dr Ahmed Amri, Head, Genetic Resources Section and formerly Regional Coordinator of ICARDA's West Asia Regional Program, for his long-standing contributions. The Ministry of Agriculture presented Dr Amri with a plaque and the Faculty of Agriculture, University of Jordan, presented him with an award for his contributions in research, teaching and advising graduate students.

The Vavilov Institute of Research, St Petersburg, awarded Dr Kenneth Street, Genetic Resources Section, the Memorial N.I. Vavilov Medal, in recognition of his "exceptional contribution to the Vavilov global collection of crop genetic resources".

Research Portfolio

In 2007, ICARDA launched a new 10-year Strategic Plan, re-aligning its research portfolio to better respond to climate change, rising food prices, desertification, and other emerging challenges within its global mandate for non-tropical dry areas. The strategy is underpinned by ICARDA's three decades of experience in the dry areas of developing countries.

The new strategy directs ICARDA's research portfolio to address both existing problems and exploit new opportunities. Programs span the entire research-for-development continuum to make sure that research outputs are relevant, and can be used efficiently for the benefit of resource-poor farming communities in non-tropical dry areas. The overall approach is integrated, multidisciplinary, and system-based, and combines research on genetic improvement, crop and resource management, and economic factors.

The Center's research is divided into four programs, as outlined below.

Biodiversity and Integrated Gene Management
This program, which aims to improve food security, nutrition and livelihoods, covers durum and bread wheat, barley, chickpea, lentil, faba bean, and forage and pasture crops. It includes germplasm enhancement, crop management practices and new genetic research methodologies.

Integrated Water and Land Management
This program, which addresses water scarcity and land degradation, is developing technologies to improve water harvesting, water productivity and supplemental irrigation, sustainably manage water resources, and support sustainable livelihoods in the context of desertification and a changing climate.

Diversification and Sustainable Intensification of Production Systems
Rural livelihoods can be transformed by intensifying and diversifying traditional production systems. Research in this program is aimed at developing integrated crop-livestock systems, strengthening market linkages, and supporting diversification into higher value crops and value-added products.

Social, Economic and Policy Research
A deeper understanding of rural poverty, livelihood strategies, and gender will help target research so that it has more impact. The social, economic and policy research in this program identifies pathways out of poverty, develops policy and institutional options to improve livelihoods, and identifies barriers to the adoption of new technologies.

All research is planned and implemented in collaboration with national agricultural research systems (NARS) through a network of seven regional programs and networks:

- **North Africa Regional Program**
- **Nile Valley and Sub-Saharan Africa Regional Program**
- **West Asia Regional Program**
- **Arabian Peninsula Regional Program**
- **Central Asia and the Caucasus Regional Program**
- **Latin America Regional Program**
- **Highland Regional Network,** serving Afghanistan, Pakistan, Iran and Turkey.

Conserving biodiversity for the future

Overview

Agriculture faces a perilous future. Climate change, depleted groundwater reserves, population growth, desertification, salinity, demand for bio-fuels and under-investment in research combine to create a potential catastrophe of frightening proportions. The need to collect and conserve biodiversity has never been more urgent – without diversity agriculture can't survive.

ICARDA and its partners have therefore developed a new strategy to help breeders find the genetic traits they need among genebank collections. This strategy has already been applied successfully to bread wheat, and now will be applied to a broad range of crops.

But genebanks aren't the only way to conserve biodiversity. Water harvesting techniques can also be used to help restore diversity to rangelands impoverished by drought and overuse. ICARDA's work in Jordan shows how contour ridging can promote a diverse and rich soil seed bank to help maintain the diversity of rangeland species.

Using FIGS to find a needle in the haystack

Plant breeders will increasingly have to screen collections for the traits needed to keep pace with rapidly changing agro-ecosystems. But finding the one trait they need among the more than 6 million accessions that exist today in the world's genebanks is a daunting task. It's not possible to screen all accessions in all genebanks for those traits essential to meet climate change, water, energy and food-security challenges.

To overcome these problems ICARDA, working with partners in Russia and Australia, has developed the Focused Identification of Germplasm Strategy (FIGS). This is used to choose (from a single genebank or from holdings around the world) subsets of accessions. that have a high probability of containing the trait of interest. To do this, they combined information on 15,000 wheat landrace accessions from their genebanks into a single database. Collection site information was then captured from historical records and GIS technology was used to add agro-climatic and soil-related data.

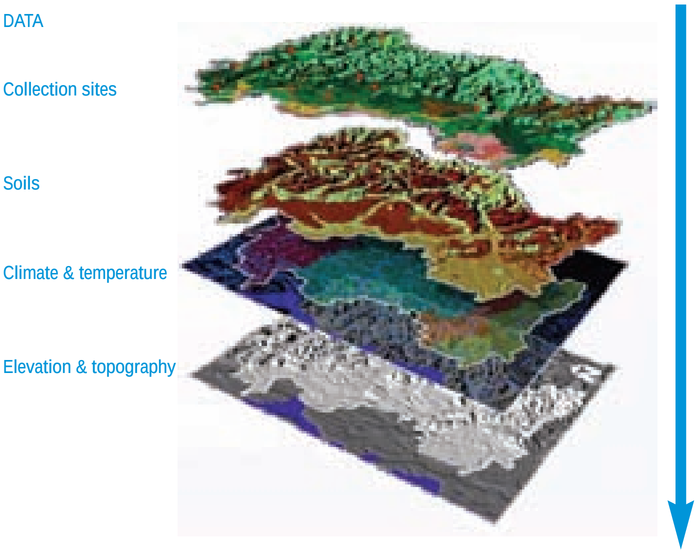
This database, together with knowledge about the distribution of pests and diseases, allowed the researchers to build small 'best-bet' subsets of bread wheat landraces and to screen them for resistance to pests like Russian wheat aphid, powdery

In 2007 ICARDA began to assemble its most valuable genetic resources ready for safe storage on a remote island in the Arctic in the Svalbard Global Seed Vault

mildew, and Sunn pest, and for tolerance to salinity and drought. As a result of this work, brand-new sources of resistance to these pests have been identified and have now entered ICARDA's breeding programs.

The method is also now being applied to barley, and a subset of 734 accessions from six genebanks will be screened for net blotch resistance at ICARDA during 2008.

The methodology is proving to be very good at identifying relatively small subsets of material that contain the variation needed. As a result, it's increased the odds of researchers being able to find that elusive trait they need to meet future challenges.



FIGS uses multiple layers of agro-climatic and geographic information about seed collection sites to predict the presence of adaptive traits in genebank accessions

Looking for genetic diversity in barley

ICARDA is also continuing its work to thoroughly explore its own barley genebank, which contains nearly 26,000 accessions, including 15,500 landraces, or 25% of the global total. From this large collection, we have recently developed a composite germplasm set (about 3000 accessions) as part of work for the CGIAR Generation Challenge Program.

Landraces make up 65% (1935 accessions) of this new composite set, and wild barley 15% (445 accessions). Selection was based on agro-climatic data on collection sites derived from GIS. The genetic diversity of the collection was then assessed using single-sequence repeats as molecular markers.

A reference sample set of about 300 accessions has also been developed which harbors more than 70% of the genetic diversity existing in the composite collection. This will be used to explore genetic diversity influencing drought tolerance in barley.

Contour plowing banks the seeds in the soil

Rangeland degradation inevitably results in lower biodiversity, and often palatable plant species (the ones that livestock like to eat) disappear completely. Understanding the biodiversity status of the rangeland and its degradation levels helps researchers develop technical and socio-economic solutions that can be used to restore rangeland vegetation and ensure that it is used sustainably.

Research conducted by ICARDA in Jordan looked at the diversity of seeds in the topsoil following the introduction of water harvesting and shrub planting in winter 2005. The total soil seed bank in December 2006 varied from over 8 million seeds of *Herniaria hirsuta* per cubic meter of soil, down to one seed per cubic meter of some other species. Samples collected in June 2007 ranged from 4.6 million seeds of *H. hirsuta* to 104 seeds of *Aspenga* species. The total number of species was 68 in 2006 and 75 in 2007.

Collecting plants to conserve genetic diversity

There were significantly more seeds in the topsoil in areas with contour plowing systems. Barley fields, native vegetation plots and catchments were not as effective at conserving the seeds of rangeland species. Contour ridges not only help in water conservation, but also trap seeds moving from the catchment, conserving these species for future collection and use. Without these ridges, this in situ seed bank would not exist and many seeds would simply wash away contributing to the further degradation of the rangeland – an important finding that can now be applied to rangeland conservation efforts in different areas.

Planting shrubs helps protect the soil and preserve fragile biodiversity in rangelands

“The FIGS approach has increased the odds of researchers being able to find the elusive traits they need to meet future challenges”

Partners

N.I. Vavilov Institute of Plant Industry, Russia
Australian Winter Cereals Collection
Grains Research and Development Corporation, Australia
National Center for Agricultural Research and Extension, Jordan

Sustaining the productivity of food legume crops

Overview

Cool-season food legumes (faba bean, lentil, Kabuli chickpea, field pea and grass pea) are a major source of protein in the diets of millions of people in South, West and Central Asia and North and East Africa. They are commonly known as 'the meat of the poor'. In dryland areas, these crops are grown under variable climatic conditions that expose them to diseases, insect pests, and parasitic weeds (mainly *Orobanche* species).

Faced with these problems, smallholder farmers are reluctant to adopt improved pulse technologies, and yields and acreages are reduced in some countries. Reduced pulse production results in shortages of protein and cash incomes among farming communities, as well as unsustainable production of cereals due to mono-cropping. ICARDA is therefore working closely with national agricultural research systems (NARS) to sustain cool-season food legume production in dry areas, using different pest-management tactics and strategies. These include (i) monitoring diseases, insect pests and weeds over time and in different areas; (ii) developing gene-pools with resistance to key pests; (iii) distributing elite resistant breeding lines to NARS; and (iv) working with NARS to promote released cultivars to farmers and validate integrated pest management.

Researchers are also aiming to breed cool-season food legume varieties adapted to variable and changing climates that may give small-scale dryland farmers a better chance of reaping a decent harvest in the face of the rising threat posed by some diseases and parasitic weeds.

Lentil is a very valuable source of protein for poor people

Monitoring diseases

In Azerbaijan, information on the viral diseases that attack chickpea and lentil plants is scarce. To rectify this, in June 2007 ICARDA's Central Asia and Caucasus Regional Program teamed up with the Genetics Resources Institute (GRI) to conduct Azerbaijan's first comprehensive virus survey. Scientists from ICARDA and GRI-Baku collected 3400 chickpea and lentil plant samples from 15 farmers' fields (12 chickpea and 3 lentil).

Laboratory tests of the samples with specific virus antibodies indicated that luteoviruses (such as *Beet western yellows virus* and *Bean leafroll virus*) were the most common viral diseases in chickpea fields. In lentil fields, however, *Pea seed-borne mosaic virus* was most prevalent, followed by *Faba bean necrotic yellows virus.*

ICARDA and GRI's findings are the first reports of *Faba bean necrotic yellows virus, Pea seed-borne mosaic virus* and luteoviruses naturally infecting chickpea and lentil crops in Azerbaijan. The monitoring efforts provided both new information and training for Azeri researchers, by showing them how to carry out surveys, recognize disease symptoms, and use laboratory techniques to detect and identify different viruses. Monitoring viral diseases in time and space will help to fine-tune ICARDA's breeding strategy and other disease-management options effectively.

Examining a chickpea field in Azerbaijan for viral diseases

Improved technologies for managing pests and diseases are benefiting lentil farmers and their families

Developing resistant gene-pools

Lentil is an important pulse crop in the Indian sub-continent, as well as in West Asia, North and East Africa, and parts of the Americas and Australia. Among the fungal diseases affecting lentil, *Fusarium* wilt (*Fusarium oxysporum* f. sp. *lentis*) is an important factor that limits yields in dry areas. Farmers in Syria, Iraq and Lebanon have, in the past, relied on a few wilt-resistant cultivars to manage the disease. Recently, however, researchers have developed new cultivars from the genetic materials ICARDA has produced as international public goods.

To do this, between 2000 and 2007, ICARDA screened 3,033 lentil landraces originating from 62 countries, and 247 wild relatives from 14 countries by growing them on soil infested with *Fusarium* wilt. The scientists found that 28% of the landraces were resistant to *Fusarium* wilt. Among the wild relatives, *Lens orientalis* and *Lens ervoides* showed good levels of resistance to the disease. The wilt-resistant lines were evaluated for agronomic traits, and those with superior traits were sent to NARS for further evaluation under conditions specific to particular areas. ICARDA legume scientists use these international testing results as feedback to improve breeding strategies designed to develop better and well-adapted breeding lines.

Progress has been made in developing gene-pools for resistance to *Ascochyta* blight in chickpea and faba bean. The selected breeding lines are being used by NARS to develop new varieties with wide and specific adaptations. What is more, many *Ascochyta* blight-resistant chickpea lines are being identified as having resistance to *Fusarium* wilt as well. Faba bean lines have been developed with resistance to both chocolate spot and *Ascochyta* blight. New faba bean lines resistant to broomrape (*Orobanche*) are also being developed and multiplied. To address diseases with eco-regional importance like rust, *Botrytis* gray mold and *Stemphylium* blight, ICARDA has forged regional collaborations with NARS in testing breeding materials in disease hot-spot areas.

> "The stable harvests from improved legume varieties ensure that smallholder farmers and their families have a reliable source of protein"

Partners

Genetics Resources Institute, Azerbaijan
Andijan Research Institute of Grain and Legume Crops and its Galla-Aral Branch, Uzbekistan
Research Institute of Plant Industry, Uzbekistan
Tashkent Agrarian University, Uzbekistan
State Varietal Testing Committee, Uzbekistan
General Organization for Agricultural Mechanization, Syria
Directorate of Agricultural Extension, Syria
Directorate of Agriculture and Scientific Research, Syria
Indian Institute of Pulses Research, India

Breeding more nutritious legumes and barley

Overview

Food legumes are a vital source of nutrients for people and animals in many countries in the developing world. One of the most important is the faba bean (*Vicia faba*), as it is an excellent source of protein, carbohydrates, and minerals. Unfortunately, however, faba beans contain compounds that can cause illness or death and that make them hard to digest. ICARDA researchers are working to breed beans with low levels of these anti-nutritional factors.

Lentil (*Lens culinaris*) is also an important staple food crop rich in protein and minerals. However, the levels of the essential micronutrients iron and zinc vary widely between lentil varieties. ICARDA researchers are working to identify and breed lentil types rich in iron and zinc. These will provide poor producers with a way of avoiding micronutrient malnutrition – a problem which underlies many diseases in developing countries.

Barley is an important staple, high-energy food. In the tropical highlands, this crop is the main source of calories for some of the poorest people in the world. Similar work to boost micronutrient contents is also being done with barley. Again, this is producing promising lines that will improve the health and livelihoods of poor families.

Making faba bean more digestible

Worldwide, about 4.5 million tons of faba bean are produced every year. As well as being a nutritious food for people, faba bean provides livestock with the important amino acids lysine and arginine when it's mixed in with their feed. Plus, when grown in rotation with cereals, legumes like faba bean also maintain soil fertility and break cycles of pests and diseases.

Unfortunately, however, faba beans contain tannins and the anti-nutritional factors (ANFs) vicine and convicine, which people, poultry and livestock find hard to digest. These anti-nutritional factors can also cause favism in some people – a debilitating and potentially lethal condition. To overcome these problems, ICARDA researchers are working to breed beans containing only low levels of these anti-nutritional factors.

Breeding toxins out of faba beans

As part of this work, faba bean breeders at ICARDA used a spontaneous mutant allele known as *vc-*, which reduces the content of both vicine and convicine in faba bean by 10–20 times. They used these materials to develop lines with lower ANFs and included them in ICARDA's Faba Bean International Low Tannin Content Nursery (FBLTCN06).

Between 2002 and 2005, researchers ran trials on these low-toxin lines of faba bean in the International Nursery. Overall, mean yields ranged from 938 to 1595 kg/ha, with 'Giza Blanca' and WRB 1-5 giving the highest yields.

The same lines were tested in Portugal, Tunisia, and Turkey, as it is important to find lines that yield well in different climates. In Antalya, Turkey, for example, these lines were not adapted to the cold and yields were very low. These breeding lines were also susceptible to multiple diseases and the parasitic weed broomrape.

Researchers are now undertaking further breeding to improve the yields of these easier-to-digest faba bean lines. This involves crossing them with high-yielding varieties resistant to cold, with combined resistance to the fungal diseases chocolate spot and *Ascochyta* blight, and with resistance to broomrape.

Breeding lentils to combat hidden hunger

During the last decade, micronutrient malnutrition – especially deficiencies of iron, zinc and vitamin A – has been identified as the underlying cause of many diseases in developing countries. This 'hidden hunger' hits the poorest hardest – especially women and children. However, lentil varieties with high levels of iron and zinc can be used to combat this hidden hunger, and ICARDA researchers are working to fast-track such varieties to farmers.

The benefits of this are obvious, as lentil is an important food in poor regions like West Asia and North Africa (WANA), and particularly in South Asia. This region accounts for about 50% of world lentil production and about 70% of world consumption, and lentil is a vital part of the diets of 1.5 billion people there.

Fast-tracking lentil with high levels of iron and zinc to farmers

Since 2004, ICARDA has screened more than 1600 lentil accessions to find micronutrient-rich genotypes, as part of the CGIAR HarvestPlus Challenge Program. These lines were found to have iron contents that ranged from 41 to 132 mg/kg, and zinc contents that ranged from 22 to 78 mg/kg. This wide variability means that there is a huge scope for breeding programs to develop lines with high iron and zinc contents that are suited to particular agro-ecological conditions.

To achieve this, high-micronutrient genotypes identified by ICARDA's researchers have been sent to national programs in Bangladesh, Ethiopia, Morocco, Nepal, Portugal, Syria, and Turkey. These national programs are then crossing these micronutrient-rich cultivars with the most popular local lentil varieties and getting them out to farmers.

Meanwhile, at ICARDA, researchers are crossing the high-micronutrient lines that they've identified in order to increase micronutrient levels even further. They are also discovering that, under some soil conditions, these high iron and zinc lentils are more resistant to certain diseases and that the seedlings establish themselves better, making them even more suitable for poor farmers. Two good examples are the varieties 'Barimasur-5' and 'Barimasur-6', which have recently been released in Bangladesh. As well as being high in iron and zinc, they produced more than 2 tonnes of seeds per hectare, on average, and are now being disseminated among farmers.

"Micronutrient deficiencies cause untold hardship to poor people in developing countries. Developing micronutrient-rich crops offers an effective way of tackling this 'hidden hunger'"

Micronutrient-rich barley is on the menu too

ICARDA's barley improvement program is also working to identify varieties rich in micronutrients. To do this, researchers have tested 334 landraces of barley collected in 34 countries. These were planted at the ICARDA research station at Tel Hadya for three consecutive years. And, in the third year, the same collection was also planted at the Breda research station where rainfall is lower. The aim was to see which varieties had consistently high micronutrient contents over time and in more than one location.

Six landraces demonstrated high iron contents in all three years and at both locations. The four landraces with the highest iron content all came from Morocco, as did one of the five landraces with the highest zinc content.

This means that the Moroccan landraces are very promising sources of iron- and zinc-rich germplasm. Researchers are therefore already working with a larger collection of landraces from Morocco to explore these findings further. And, all the micronutrient-rich entries identified in this study have been included in the ICARDA barley breeding program.

Nepal's lentil variety 'Shekhar' has a high level of iron (83.4 mg/kg). So it is very important in the diets of poor people, especially pregnant women and pre-school children. 'Shekhar' was developed by national breeders using germplasm supplied by ICARDA, and is now widely grown in the lowland Terai region.

Partners

Bangladesh Agricultural Research Institute
Grain Legume Improvement Program, Nepal
Ethiopian Institute of Agricultural Research
General Commission for Scientific and Agricultural Research, Syria
Institute of National Research on Agronomy, Morocco
CGIAR HarvestPlus Challenge Program

Boosting the benefits gained from shrinking water supplies

Overview

Almost all the fresh water resources available in the dry areas are already being used. More demands are being placed on the water that is available as populations boom and people's living standards rise. And global warming is likely to further reduce the amounts of water available.

So, if we can't increase the amount of water that's available to agriculture in the dry areas, what can we do? The answer is that we can increase the productivity of water that is available by producing 'more crop per drop'. Or even 'more calories per drop' or 'more cash income per drop'. To achieve these goals, ICARDA is pioneering, testing and adapting new technologies and new crop management options, ranging from new water-use-efficient varieties to better ways of irrigating.

Future-proofing water use in agriculture

Food and fiber production currently uses over 75% of the water resources available in the dry areas. But, agriculture is going to lose more and more of this supply as more water gets diverted to domestic, industrial and other priority sectors. The share of water available to agriculture in countries in North Africa, for example, is likely to drop from 75% to about 50% by 2050.

ICARDA is therefore working to increase the benefits that farmers get per cubic meter of water used. And, the good news is that we are finding that there is great potential to achieve this.

Improving water productivity – what does it mean in practice?

Raising water productivity isn't just about producing more biomass for every drop of water. In fact, increases in water productivity can mean (i) growing more food per cubic meter of water, (ii) increasing the income farmers get from every cubic meter of water, and (iii) increasing the calories produced per cubic meter of water.

These three types of water productivity can vary greatly between crops. Researchers therefore have to consider all three types in relation to farmers' livelihoods: is food security or cash income more important? Potato, for example, gives low economic returns per unit of water used (up to US$0.7 per m^3). But it does provide large amounts of calories and biomass per unit of water. By contrast, olives give a much higher economic return (up to US$3.0 per m^3), but not much food. Efforts to improve water productivity also need to be applied at a range of scales (plant, field, farm and basin) to maximize the benefits from the water used.

Trials like this one on supplemental irrigation in Karkheh (Iran) have successfully improved water productivity – giving more crop for every unit of water used

In partnership with farmers and national researchers in the region, ICARDA is therefore working to boost agricultural water productivity through improving:

(i) water management – by making the best use of available water using techniques like water harvesting and supplemental irrigation
(ii) crop management – by using techniques like mulching and conservation tillage to keep moisture in the soil for plants to use
(iii) germplasm – by breeding more water-use-efficient varieties that yield more using less water
(iv) institutions – by promoting ways of forming and empowering community/resource-user groups able to take responsibility for managing their water for best use
(v) policies – by developing new policy options that ensure an enabling environment that encourages the adoption of improved agricultural options and technologies.

Planting early using supplemental irrigation

A good example of ICARDA's efforts in these areas is its work on supplemental irrigation in rainfed systems. Working together, researchers and farmers have found that water productivity can be greatly increased by applying limited amounts of supplemental irrigation at specific times over the crop's growing period.

In the highlands of Turkey (central Anatolia) and Iran (Maragheh and Karkheh), for example, ICARDA introduced the idea of supplying small amounts of supplemental irrigation to allow crops to be sown earlier than usual. Normally, farmers there have to wait for the rains. But, sowing wheat early (using 50–70 mm of water) makes it possible for crops to get established quickly, before the winter frosts strike. It also avoids the risks associated with the rains coming late and allows the crops to maximize their growth when the rains do come. This means that grain is produced well before the hottest summer temperatures arrive. As a result, the amount of wheat grain produced per cubic meter of water increased more than three fold in the trials in central Anatolia (from 1 kg to 3.7 kg) and more than five fold in Karkheh (from 0.5 kg to 2.75 kg).

Making the most of water with deficit supplemental irrigation

Another way forward that ICARDA is pioneering is the use of 'deficit supplemental irrigation'. This involves getting farmers who are already irrigating their crops to apply less water than normal, in order to increase water productivity – boosting the benefits they receive per cubic meter of water used.

The technique has been very successful in the lowlands of Syria, Tunisia, Morocco and Iran, nearly doubling water productivity over normal irrigation methods. In Syria, for example, farmers were able to use 50% less water than normal, while yields were only 10–15% lower than with full supplemental irrigation. The water saved in this way was then available to irrigate more fields – meaning that total farm production could be boosted by around 34%. Alternatively, in areas where groundwater is being overused, the water saved can just be left in the in the ground, helping to avoid the many agricultural and environmental problems caused by extracting too much groundwater.

Overall, ICARDA's research on supplemental irrigation showed that the water productivity of grain crops can be increased from an average of about 1.0 kg per cubic meter of water under full irrigation to over 2.5 kg per cubic meter of water under the new regime. As part of this work, ICARDA has also developed an easy-to-use chart to help farmers in different rainfall zones identify the most profitable amounts of irrigation to apply, based on water costs and crop sale prices.

Better germplasm and crop management

Planting improved varieties also improves water productivity, as shown by trials in Karkheh (Iran) and Aleppo (Syria), for example. There, using winter-adapted varieties of wheat and chickpea (which benefited from a longer growing season and lower evaporation losses) increased the productivity of rainwater by 30% and 35% respectively, compared with varieties that could only be planted in spring under warmer conditions.

Also in Karkheh, research showed that applying 50 kg of nitrogen per hectare when wheat crops receive supplemental irrigation in the spring can boost water productivity by about 25%. And, other crop management practices (such as weed and disease control) can also be used to increase productivity and reduce water losses through evaporation.

Using small amounts of supplemental irrigation to plant crops early means that they use water more efficiently

> "ICARDA is working to increase the benefits that farmers get per cubic meter of water used"

Partners

CGIAR Challenge Programme on Water and Food
Agricultural Research, Education and Extension Organization, Iran
Ankara Research Institute for Rural Services, Turkey
Institut National Agronomique de Tunisie, Tunisia
General Commission for Scientific Agricultural Research Syria
Institut National de la Recherche Agronomique, Morocco
International Fund for Agricultural Development
Arab Fund for Economic and Social Development
OPEC Fund for International Development

Making an impact: research benefits chickpea and crop–livestock farmers

Overview

In the low-lying areas of West Asia and North Africa, farmers traditionally plant chickpeas (*Cicer arietinum*) in spring, after the main winter rainfall is over. This often leads to poor yields because the crop later faces drought and heat stress.

ICARDA scientists have been tackling this problem in two ways: by breeding drought-resistant chickpea varieties and by encouraging farmers to plant the crop during winter. Part of this work involves ICARDA distributing advanced breeding lines for partners to develop – which means that these lines are valuable international public goods. Impact studies show that these efforts are boosting household incomes (especially among poor farmers), providing employment opportunities, and helping to ensure that producers achieve reasonable yields even under drought.

ICARDA's Developing Sustainable Livelihoods of Agropastoral Communities of West Asia and North Africa Project (known as the Mashreq/Maghreb Project III) has also had real, on-the-ground impact, in successfully creating and using a community-development approach that has improved the lives of crop–livestock farmers. A field manual designed to guide the production of a participatory community development plan was published in 2007, and will be useful to practitioners around the world. The project's website has also recently gone live at www.mashreq-maghreb.org.

Drought-resistant chickpea varieties boost yields

ICARDA researchers have detected differences in the alleles conferring high chickpea yields in low-yielding environments as against those conferring high yields in favorable environments (where there are more inputs and adequate rainfall). Using this knowledge, they have identified genotypes that give high yields with low inputs, and that also respond well to supplementary irrigation. By also factoring in traits like early seedling establishment, early growth vigor and canopy development, and early flowering and maturity, they've been able to identify potentially useful lines. Following pedigree breeding, these lines (which are both *Ascochyta* blight and cold tolerant) have been distributed to national research systems for evaluation.

ICARDA chickpea seed for winter sowing helps crops avoid stress from drought

One of the lines shared (FLIP 87-8C) was sent to Turkey, a major Kabuli chickpea exporter, in 1991. After outperforming other varieties in in-country field trials, it was released for general cultivation in 1997 under the name of 'Gokce'. The Exporters' Union Seed and Research Company (ITAS), a non-profit organization set up by Turkish agricultural exporters, conducted a large and successful technology-transfer and seed-production program, which was instrumental in getting 'Gokce' to farmers. These efforts, and the fact that 'Gokce' has many useful characteristics – it is drought-tolerant and the plants can be harvested using a combine for example, because they grow erect and reach about 35 cm in height – ensured that producers in Turkey quickly adopted the variety. In fact, 'Gokce' is now planted on a remarkable 360,000 to 400,000 hectares, accounting for 60-65% of the country's chickpea-growing area. In many of Turkey's major chickpea-producing regions, the area planted to 'Gokce' reaches 85%.

Has this new option really made a difference to producers? The answer is a definite 'yes'. As 'Gokce' cultivation has expanded, average chickpea yields in Turkey have increased from 861 kg/ha in 2000 to 1071 kg/ha in 2006. And further proof of the impact that 'Gokce' is having is given by the fact that this year farmers in Central Anatolia are expecting chickpea yields of about 1500 kg/ha despite the fact that other crops have been devastated by a severe drought.

Encouraging winter-sown chickpeas

Yields of spring-sown chickpeas in Syria have been falling over recent years. So, ICARDA scientists have been working to develop winter-sown varieties to counter this trend. The results are varieties that bring with them a range of advantages – they are *Ascochyta* blight tolerant, allow the use of more sustainable farming systems that make more productive use of the land, and take advantage of the higher levels of rainfall available in winter.

Of course, developing varieties that perform well when sown in winter is only part of the solution. Farmers also have to be persuaded to use the new technology. To encourage farmers to shift to winter production using improved varieties, ICARDA worked with the Department of Agricultural Extension to put together a package based on the varieties 'Ghab 3', 'Ghab 4' and 'Ghab 5' (which were derived from ICARDA breeding lines).

As a result, the area under winter-sown chickpea is expanding in Syria. This is particularly noticeable in drier regions, like Aleppo province, that are not traditional chickpea-growing areas. Adoption intensity is higher for better-off farmers, as poorer farmers are more risk-averse and prefer to see the positive effects before adopting the new technology themselves. However, adoption is still increasing at an accelerating rate, and is expected to reach its maximum of 90% by 2015.

The benefits are obvious, as winter-sown chickpea technology has increased yields by about 18% in the drier areas and 32% in other parts of the country. All farmers, poor and better-off, earned increased incomes. These are major considerations when you take into account that chickpea contributes about 21% to the average household's income of about US$13,900 – with winter chickpeas accounting for 14% and the spring crop for 6%.

Winter-sown chickpea has a higher water-use efficiency, produces tall plants suitable for mechanization, and escapes drought and heat.

ICARDA's Mashreq–Maghreb Project works with communities, to help them to create their own Community Development Plans

ICARDA's approach to real participation receives the government seal of approval

Traditional top-down approaches to agricultural research and development usually fail to truly empower farming communities. A far better alternative is to use integrated participatory approaches that lead to more efficient resource management and more effective poverty-reducing policies. But to achieve this, local communities need to take part in all phases of the development process.

The ICARDA Mashreq–Maghreb Project responds to this challenge by partnering with national agricultural research systems and agropastoral communities in selected West Asian and North African countries. It helps prepare and implement community development plans, aimed at building sustainable livelihoods for agropastoral communities in the dry areas of the region.

The Project has succeeded in providing an effective framework for the real participation of communities in reaching solutions to their priority livelihood issues. It produced a useful manual in 2007, to guide similar efforts around the world.

The approach developed has received widespread approval by all stakeholders, so much so that it has been embraced by governments and formally adopted as a standard method for the implementation of all agropastoral community development plans in Algeria, Morocco, and Tunisia.

"This year, farmers in Central Anatolia are expecting yields of about 1500 kg/ha, while other crops have been devastated by drought"

Partners

Exporters' Union Seed and Research Company, Turkey
Central Research Institute for Field Crops, Turkey
Turkish General Directorate of Agricultural Enterprises
Department of Agricultural Extension, Syria
General Commission for Scientific Agricultural Research, Syria
National agricultural research systems in Algeria, Iraq, Jordan, Lebanon, Libya, Morocco, Syria, and Tunisia

Stem rust Ug99: countering a global threat to food security

Overview

Stem rust is one of the most destructive diseases of wheat, and causes crop losses of up to 60% in some countries. It is particularly feared in the Central and West Asia and North Africa (CWANA) region, where per capita wheat consumption is among the highest in the world.

The most economical and environmentally friendly solution to stem rust is to grow wheat cultivars that are genetically resistant to the pathogen. This strategy has worked for several decades. But in 1999, a new physiological race of the stem-rust fungus (called Ug99) appeared in eastern Africa. Given the long distances rust spores can travel, it was soon clear that Ug99 poses a serious risk to global food security. By 2007 it had spread as far as Iran. It is now threatening South Asia, and may eventually hit East Asia (see map).

In response to advocacy from Nobel Laureate Dr. Norman Borlaug, a global consortium was founded in 2005 that included ICARDA, the International Maize and Wheat Improvement Center (CIMMYT), Cornell University in the USA, and FAO. The goal of the consortium, now known as the Borlaug Global Rust Initiative (BGRI), is starkly simple: to prevent a pandemic. It is working to create new cultivars resistant to Ug99 and get them into farmers' hands as quickly as possible.

The search for resistant cultivars

ICARDA's Spring Bread Wheat Improvement Program is working to identify urgently sources of resistance to the new race of stem rust, by screening current and retired wheat varieties at Ug99 hotspots in Ethiopia and Kenya. The goal is to quickly provide alternatives that can be used as emergency replacements for susceptible varieties and to discover as-yet-unknown resistance genes that can be incorporated into the breeding program.

ICARDA is therefore coordinating germplasm screening in Ethiopia in collaboration with the Ethiopian Institute of Agricultural Research (EIAR), while similar work is taking place in Kenya under CIMMYT coordination with Kenya Agricultural Research Institute (KARI). In 2007 over 10,000 entries were screened at the two sites and scientists found that 14–20% contained resistance to Ug99.

Another set of trials composed of 249 lines was screened in Kenya under the most virulent form of Ug99. Results revealed that 6% of the lines could potentially be used to replace current susceptible wheat varieties. Lines found to be resistant have been made available to national agricultural research systems (NARS) worldwide as an international public good for further multiplication, release and distribution through national systems including extension services. Several other high-yielding and resistant lines are in the pipeline. Lines that are both resistant and highly productive are good candidates to replace susceptible varieties.

Another part of the puzzle involves developing new cultivars with durable resistance to Ug99. The ICARDA program is

Trials at the Debre Zeit research station in Ethiopia: the race is on to find wheat varieties resistant to the Ug99 stem-rust fungus breeding cultivars with durable resistance, for high-risk areas in East Africa and the migration path, to avoid further breakdown of resistance to the pathogen. It's also breeding race-specific genes into targeted varieties and promising new wheat varieties in secondary risk areas, such as facultative/winter wheat areas in high-latitude, high-altitude regions like Turkey and Central Asia. Using race-specific genes in combination like this enhances resistance over the long term.

This approach, applied to genes that have not been used previously, will also enhance genetic diversity for resistance within and between zones in the CWANA region.

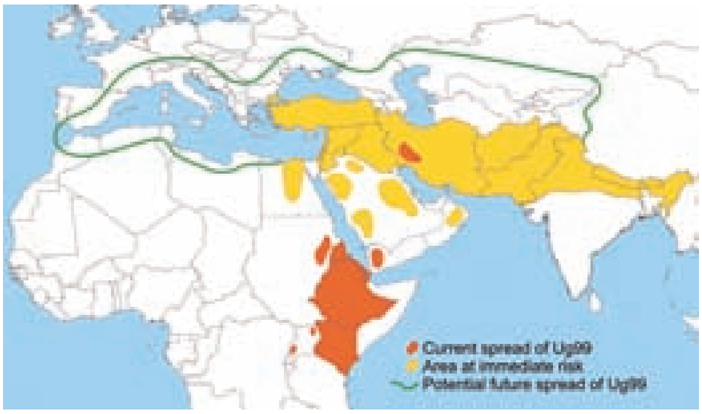
Getting resistant seed to farmers quickly

Flexibility is crucial when responding to imminent danger. But bureaucratic processes and legal hurdles are real obstacles to the quick dissemination of public-sector research and the distribution of new seed. With the threat to global wheat production posed by stem rust, it's crucial to change the status quo – and fast. One of the BGRI's key aims is to multiply and produce seeds resistant to the pathogen much more quickly. ICARDA's Seed Unit is working on this job in collaboration with a broad range of partners – NARS, public and private seed companies, NGOs and farmers.

One component of this effort is 'micro increase' of wheat lines that show promise in resisting the pathogen. Early in the breeding process, scientists identify resistant, well-performing lines for fast-track multiplication. These are planted under rigorous controls to 'purify' the variety and produce enough seed for further testing and distribution to NARS. Normally the seeds would not be multiplied without the official approval of the variety from the National Variety Release Committee.

Another fast-track strategy is off-season seed multiplication. After three promising bread wheat lines were identified in Ethiopia by CIMMYT, ICARDA provided financial and technical support to multiply their seeds during the off season using irrigation. One of the lines was officially released by the National Variety Release Committee in April 2007, as 'Barkumme' (meaning 'millennium'). The off-season multiplication produced 20 tons of seeds, of which the Ethiopian Institute of Agricultural Research retained 2 tons for research and popularization purposes. The remaining seed was released to the Ethiopian Seed Enterprise, a national seed supplier for large-scale seed production and nationwide distribution. It also went to state farms and an international NGO working with farmers in technology demonstrations, reaching over 100 villages and initiating informal farmer-to-farmer diffusion which will continue in coming years.

Wheat infected by stem rust; severe infections can kill the plant



Areas at risk from the stem rust epidemic caused by a dangerous new race of the rust fungus called Ug99.

Ug99 is spreading fast, and threatening globally important wheat-growing areas.
Source: Global Rust Initiative, www.globalrust.org

> "Our goal is to create new wheat cultivars resistant to the new strain of stem rust and get them into farmers' hands as quickly as possible"

Partners

Borlaug Global Rust Initiative
Ethiopian Institute of Agricultural Research
Ethiopian Seed Enterprise
CIMMYT – International Maize and Wheat Improvement Center
Kenya Agricultural Research Institute

Battling bugs to boost the breadbasket

Overview

Wheat is an essential crop for people living in dryland areas, accounting for 45% of the daily calories eaten in West and Central Asia and North Africa. But with only 1.5 tons being produced per hectare, productivity is very low – considerably less than the world average of 2.8 tons per hectare.

Insect pests like Sunn pest (*Eurygaster integriceps*) and Russian wheat aphid (*Diuraphis noxia*) are a major reason for this, and ICARDA is working to develop new integrated pest management methods to combat them.

Part of this strategy involves working with wheat genetic stocks originally collected from both the wild and farmers' fields and then further developed and tested at our Tel Hadya research station in Syria. The vigorous bug- and aphid-resistant wheat types that ICARDA is identifying are providing an important genetic base for raising crop yields and farm profits.

This work is complemented by research to identify and use insect-killing fungi to control Sunn pest numbers. Fungal samples are being refined according to spore production and virulence against Sunn pest, with the best being used to make granules and sprays for use in wheat fields.

ICARDA-bred wheat lines resistant to Sunn pest (right) easily outstrip susceptible lines (left)

Identifying crop resistance

Sunn pest is decimating wheat crops in Eastern Europe and West and Central Asia, partly by reducing yields by feeding on the wheat's leaves, stems and grains, and partly by making any grain harvested unusable. This happens because enzymes in the bugs' saliva damage the grain, which means that bread made from flour ground from the infected grain won't rise properly. Even if only 2–3% of the grain in a field is damaged like this, the entire harvest can be ruined. Similarly, in North Africa and West Asia, field crops are being threatened by the Russian wheat aphid, which again damages the plants and injects a toxic saliva.

Using wheat plants that are resistant to insect attack is the most economical and practical means of controlling bugs and aphids. But to breed resistant plants most effectively, breeders and geneticists must first build up a genetic base by collecting specimens from a wide variety of provenances. For this reason, a team led by ICARDA has spent the last decade evaluating seeds of domestic wheat (*Triticum* species) and its wild relatives (*Aegilops* species) collected in West and Central Asia and North Africa to determine their resistance to pests.

During five years of experimentation at the ICARDA field station in Syria, the entomologists introduced Sunn pest bugs to wheat plants grown inside mesh cages and then evaluated the plants for resistance to attack. A similar study took place at the same location to assess the damage caused by Russian wheat aphid.

In the Sunn pest study, of the 5000 or so wheat lines and wild relative accessions examined, 26 showed moderate resistance to the insect. Only one specimen of *Aegilops*, originating from Morocco, and one specimen of *Triticum*, bred at the ICARDA research station in Syria, were undamaged by the bugs. The Russian wheat aphid study was more prolific, revealing 32 resistant specimens. Of these, one *Aegilops* specimen, originating in Syria, and five *Triticum* specimens, originating in West Asia (Syria, Iran, Iraq, Turkey) and Armenia, showed the lowest number of rolled or yellowed leaves.

The resistant lines of wheat identified in the Sunn pest and Russian wheat aphid studies show promise for providing high yields of undamaged wheat for farmers. All are being developed further in ICARDA breeding programs to develop new varieties for commercial use.

Killing insects with fungi

Another way of reducing crop damage caused by insects is to use a biological control. To develop a control using insect-eating fungi, ICARDA teamed up with the University of Vermont (USA), CABI Bioscience (UK), and national agricultural research systems in West and Central Asia. Over the last 11 years, the team has identified around 260 samples of fungi that attack Sunn pest bugs.

Preliminary studies showed that, in sprays applied during the spring, fungal samples extracted from summer populations of Sunn pest bugs had more impact than those taken from overwintering insects. For this reason, entomologists spent the summer of 2007 conducting an additional survey in the wheat-growing areas of Syria. The team collected 1550 Sunn pest adults, which they later examined for fungal growth in the laboratory. From this collection, the entomologists recovered six new samples of insect-eating fungi.

The next stage in ICARDA's research is to find out which fungal culture does most damage to Sunn pest bugs. The team will also assess each culture's ability to produce spores under different temperatures. These findings will allow agriculturists to develop a fungal control with maximum impact in the field, increasing wheat yields for commercial farmers.

A new isolate of a fungus, found by ICARDA researchers in 2007, will help develop biological methods to control Sunn pest

Integrating gene management

ICARDA's work on fighting insect pests is in line with goals of its Integrated Gene Management research program, namely to improve genetic stocks of wheat and develop integrated pest management techniques. By collecting specimens of fungi and wheat (both wild and domesticated) the research teams have conserved valuable genetic resources from unique arid ecosystems. These resources are critical for breeding vigorous plants and producing hard-hitting fungal sprays.

Pest-resistant plants and fungal controls are a key step forward in the quest to maximize dryland wheat yields and improve food security for the rural poor in the long term. Climate change, which has massively reduced global wheat supplies by bringing cold weather, floods and widespread drought, adds urgency to the situation. And, as wheat prices rise rapidly, driven by global demand for biofuels and the need to produce animal feed (because developing nations are growing wealthier and consuming more meat), efforts to increase home-grown yields have never been more pertinent.

Testing wheat lines and wild relatives for resistance to Russian wheat aphid: resistant germplasm (right) offers the promise of higher, more stable yields

> "If the region is to have any hope of meeting the food needs of its people in the decades ahead, major constraints to production, including Sunn pest, must be overcome"

Partners
University of Vermont, USA
CABI Bioscience, UK
National agricultural research systems

Using molecular genetics to enhance drought tolerance in barley

Overview

Using new techniques, ICARDA researchers working to improve drought tolerance in barley have identified a large number of different alleles in ICARDA's holdings, including many that are rare. This diversity makes it highly likely that ICARDA's barley germplasm collection contains many alleles for drought tolerance and other useful traits – a possibility which will now be investigated as a matter of priority.

ICARDA is also working to address the fact that variation in many important traits (such as tolerance to environmental stresses like drought) cannot simply be explained by DNA coding for proteins. The amount of gene expression is also important. Our researchers have therefore developed new methods that use an allelic imbalance test to detect *cis*-acting DNA sequences – those that influence the expression of other genes. This provides a new way to tap into a treasure trove of genetic diversity in crops.

Identifying genetically diverse barley in ICARDA's collection

Using improved techniques to examine large numbers of accessions means that residual linkage disequilibrium (LD) can now be exploited to identify major genes or quantitative trait loci (regions of DNA that determine complex traits) which are tightly linked to genetic markers. To help with its work to increase drought tolerance in barley, ICARDA has applied this association mapping technique to 223 barley genotypes – 185 accessions of *Hordeum vulgare* and 38 accessions of *H. spontaneum*. These genotypes were drawn from 30 countries on four continents: Africa, Asia, Australia, and Europe.

In the 223 genotypes, researchers found 143 alleles using 68 single nucleotide polymorphism (SNP) markers and 356 alleles using 45 simple sequence repeat (SSR) markers. The allelic data were used first to produce a genetic similarity coefficient matrix, and then a dendrogram that showed all the genotypes and how closely they are related.

The dendrogram showed that the spontaneum and vulgare accessions were mostly found in two separate clusters, meaning they were quite different genetically. One cluster contained 174 vulgare accessions, while in several sub-clusters genotypes were

This trial contains a mix of cultivated barley (*Hordeum vulgare*) landraces from diverse origins; ICARDA is working to tap these plants' genetic diversity, in order to boost yields under different conditions

grouped by geographic regions. Some clusters, however, were from a mixture of regions.

Researchers also analyzed the genetic diversity according to location, by splitting the original genotypes into six pools (Africa, Middle East Asia, North East Asia, the Arabian Peninsula, Australia, and Europe). Accessions from Middle East Asia and North East Asia displayed the most diversity with 6.4 and 5.8 alleles per locus respectively. The material from these areas also contained more rare alleles and more genotypes carrying rare alleles.

Overall, across all locations, spontaneum accessions had more genetic diversity – in terms of total number of alleles and number of alleles per locus – than did either the vulgare landraces or the improved genotypes of vulgare. However, vulgare landraces showed greatest diversity in terms of the genetic similarity value.

Vulgare landraces contained more rare alleles (93) than either the spontaneum accessions (29) or the vulgare improved genotype groups (7). However, it must be remembered that 163 vulgare landraces were analyzed, as opposed to just 38 spontaneum accessions.

In summary, the gene-based SNP and SSR markers showed that ICARDA's germplasm contains a high level of genetic diversity. And, while the spontaneum gene pool contained more alleles, the majority of rare alleles were found in the vulgare landraces. The genotypes with alleles specific to regions, and alleles unique to genotypes, may prove very useful for breeding resistance to pest and diseases, and tolerance to abiotic stresses like drought, into elite barley lines. So, the vast allelic diversity identified in ICARDA's germplasm will now be exploited through trait mapping, to help improve barley varieties by boosting traits like drought tolerance.

Genes regulated during drought and development identified

In recent years, analysis of genetic variation has focused on the study of changes in DNA coding for proteins. However, it is increasingly clear that this only accounts for one aspect of genetic variation. For many traits (notably tolerance to environmental stresses like drought), the amount and regulation of gene expression is of great importance – the more strongly a drought-tolerance gene is expressed, for example, the better a plant will be able to tolerate drought. ICARDA – together with advanced research institutes – has now developed a robust new approach based on allelic imbalance assays to overcome this. Based on monitoring gene expression in experimentally created hybrids, this approach is particularly suited to work with crop plants.

Importantly, the approach is robust and scalable, and ensures that the *cis*-acting elements (DNA sequences which control the action of other genes) detected will be of maximum benefit to plant improvement efforts. As a result, this work is providing a new way to unlock the potential of a yet untapped reservoir of genetic diversity in crops.

As part of this work, ICARDA conducted allelic imbalance assays to identify genetic variation affecting drought tolerance.

Thirty genes were tested for allelic imbalance in five crosses and reciprocal crosses at two developmental stages (vegetative and generative) and under two treatments (control and drought). Of these genes, 29 showed allelic imbalance in at least one cross. Altogether, 54% of the 82 gene/cross combinations tested showed allelic imbalance. The percentage of genes with allelic imbalance varied between crosses.

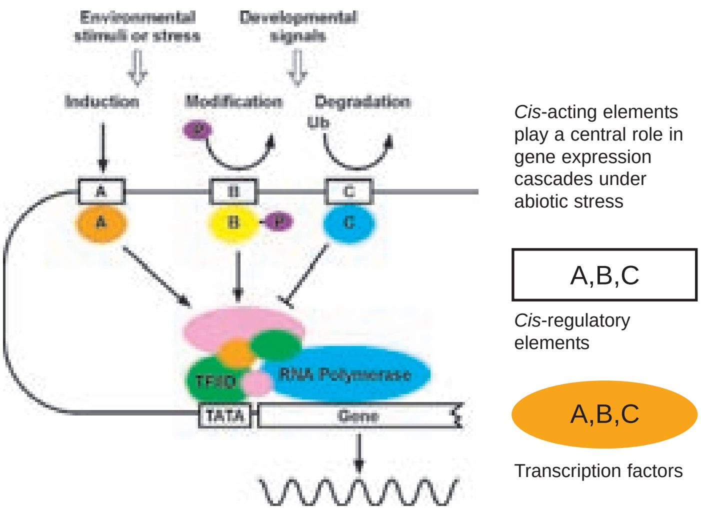
Drought affected allelic expression in seven genes and 10 gene/cross combinations. The effect of drought on allelic expression was pronounced in the cross between wild barley and the cultivated variety 'Alexis', with 5 of 15 genes showing changed allelic expression between control and drought conditions. This is the effect of *cis*-elements that are regulated under drought.

Overall, more than 50% of the barley genes assayed were *cis*-regulated. Some gene/cross combinations exhibited strong allelic imbalance, to the degree that only one parental allele was expressed. These strong differences in allelic expression in barley, an inbreeding species, clearly show that regulation of expression plays a prominent role in determining phenotype.

> “Molecular genetics provides a new way to tap into a treasure trove of genetic diversity in crops”

The fact that we found *cis*-elements responsive to drought is a first step towards understanding regulatory gene networks in stress-response cascades. Manipulation of *cis*-acting regulatory units in breeding will allow targeted improvement of drought tolerance through adaptation of gene expression.

Detection of *cis*-regulatory variation in barley



Partners

Ministry for Technical Cooperation and Development, Germany
Leibniz Institute of Plant Genetics and Crop Plant Research, Germany
Wageningen University and Research Centre, the Netherlands
International Crops Research Institute for the Semi-Arid Tropics
CGIAR Generation Challenge Programme

Unlocking DNA to breed more drought-tolerant barley and durum wheat

Overview

Breeding drought tolerant varieties is not easy, partly because drought tolerance is not controlled by one gene but by many – what geneticists refer to as 'quantitative traits'.

QTLs are the areas of DNA associated with the alleles controlling traits like drought tolerance. Identifying them means that breeders can make sure that new crosses contain the desired range of QTLs, so combining desirable traits like drought tolerance and high yields. The technique is also considerably shortening the time needed to produce new cultivars.

Results from both barley and durum wheat studies have identified large numbers of QTLs that will be useful to breeders in the future.

Using QTLs to breed barley for specific locations

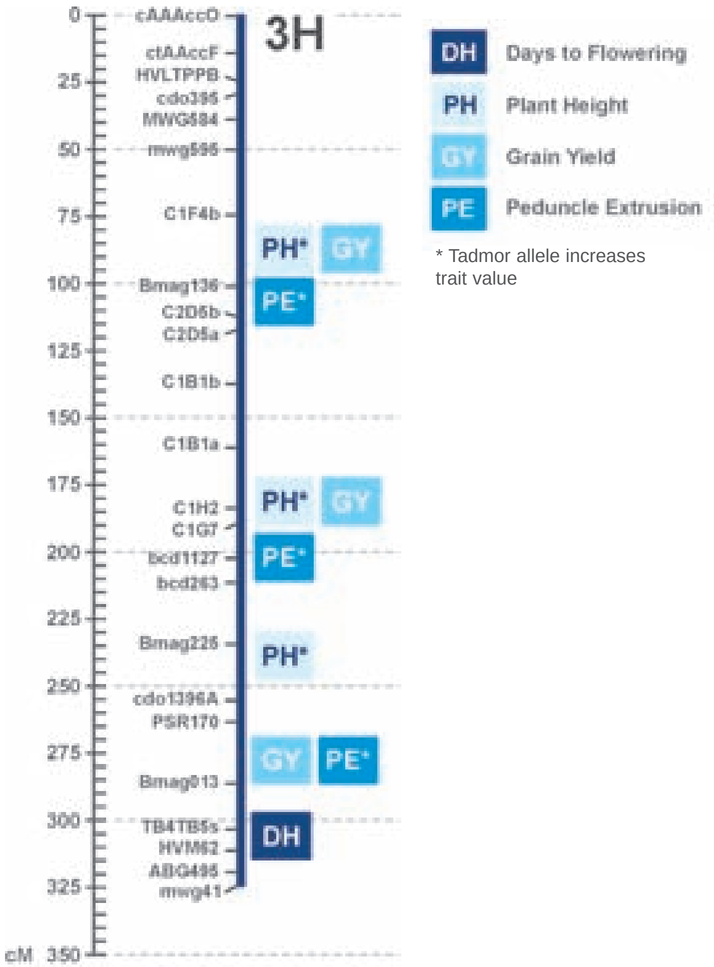
More drought tolerant varieties of barley need to be bred in order to boost yields and ensure that this widely grown crop performs well in specific environments. Global warming makes this work even more urgent, because it will bring more frequent droughts and change the areas in which barley is cropped.

Recent work in this area has made use of a barley mapping population made up of 158 recombinant inbred lines (RILs). These were derived from the landrace 'Tadmor' (which is well adapted to the driest locations in Syria) and the breeding line 'ER/Apm' (which can give high yields under conditions of moderate drought stress).

Between 2002 and 2005, the RILs were grown in rainfed field trials at four locations in Syria and Lebanon, alongside the two parent lines. During this time, the researchers analyzed a wide variety of traits, including water use efficiency, grain yield, and the number of days it took plants to reach maturity after emerging. This data was then combined with work to identify QTLs using 165 molecular markers. This provided a range of useful findings.

Researchers found, for example, that most of the main effects on agronomic traits were on chromosome 3H, and that these mainly affected yield, peduncle extrusion and plant height (see Figure 1). Alleles from 'Tadmor' increased plant height and peduncle extrusion and decreased grain yield. Alleles from 'ER/Apm', on the other hand, increased average yield over all sites and seasons. Six QTLs coincided between yield and plant height, indicating that average grain yield was mainly determined by plant height.

Figure 1. The new QTLs found on chromosome 3H, which can be used to breed more drought-tolerant plants.



Four markers with interactions were mapped close to known genes for drought tolerance. When the experimental sites were placed in two groups according to high drought stress (Breda and Terbol) and moderate drought stress (Tel Hadya and Kfardane), pHva1 was a significant marker showing the favorable effect of 'Tadmor' alleles at Breda and Terbol (see Figure 2). Interestingly, pHva1 is a marker for the HVA1 gene, which has been used to improve drought and salt tolerance in wheat, oats, and rice.

Crossover interactions showed that different trait expressions and different QTLs improved yield at different locations, which means that alleles that are beneficial in one location may be a problem in another. 'Tadmor' alleles, for example, conferred greater plant height and a shorter period of grain filling and

Figure 2. The 'Tadmor' allele at pHva1 increased barley yields at Breda and Terbol (high drought stress), but decreased yields at Tel Hadya and Kfardane (moderate drought stress).

increased yields at Breda and Terbol where drought stress was high. At Tel Hadya and Kfardane, however, where drought stress was moderate, they actually decreased yields.

The results obtained should enable the targeted inclusion of alleles for tolerance to severe drought (such as those identified in 'Tadmor') at specific sites. This will mean that breeders will be better able to match cultivars to different environments. In comparison with traditional breeding methods, the work being done will greatly shorten the time required to produce new cultivars.

Drought tolerance QTLs found for durum wheat

Durum wheat (*Triticum turgidum* var. *durum*) is a staple crop in much of North Africa and West Asia, where it is used to produce everyday foods such as couscous and pasta. Unfortunately, however, durum wheat's growth, development, and yield are all badly affected by drought. So, breeding drought-tolerant varieties is a priority, especially as droughts are going to become more frequent as global warming worsens.

One way to speed up the breeding process is to use molecular markers to identify quantitative trait loci (QTLs) and map the genes that are expressed by durum plants displaying various drought-tolerant characteristics. Recent analyses of a mapping population produced by crossing 'Jennah Khetifa' with 'Cham 1' have identified a large number of such QTLs.

This mapping population was grown in Syria at Tel Hadya (average annual rainfall of 330 mm) and Breda (average annual rainfall 250 mm). Researchers then recorded grain yield and plant characteristics related to drought tolerance (such as chlorophyll content, fluorescence index, osmotic adjustment, and transpiration efficiency).

Analyses showed that two traits related to drought tolerance (leaf osmotic potential and osmotic potential at full turgor) were only associated with one QTL each. However, multiple QTLs were associated with the other traits, ranging from 3 QTLs in the case of leaf relative water content to 43 for canopy temperature depression.

In many cases, one QTL was associated with a number of traits. This indicates that the same gene, or closely-linked genes, affect different traits. For example, one QTL was associated with canopy temperature depression, photosynthetically active radiation absorption, water index, and quantum yield. Researchers also found that QTLs for carbon isotope discrimination and transpiration efficiency were mapped to the same locus (gwm389).

Candidate drought-tolerance genes were also compared with differentially expressed sequence tags (ESTs) known from barley. This was done because if they coincided it would indicate that particular known genes may be involved in durum drought responses. The researchers found that QTLs for drought tolerance and candidate genes/ESTs did indeed coincide on a number of chromosomes (1B, 2A, 3B, 4B, 5A, 5B, 6A, 6B, and 7B).

Overall, four candidate genes and 10 differential ESTs were found to be associated with drought-tolerance QTLs. These results indicate considerable potential for marker-assisted selection to improve durum drought tolerance more rapidly than was previously possible.

“The work will greatly shorten the time required to produce new varieties”

Partners

Ministry for Technical Cooperation and Development, Germany
Montpellier SupAgro, France

Participatory plant breeding: turning the traditional model on its head

Overview

A new way of working is turning the traditional model of research on its head in arid regions in Africa, the Middle East and West Asia. Farming in these environments is difficult and poverty is widespread because yields of staple crops such as barley are chronically low, and often fail altogether. Conditions are harsh, temperatures are extreme, rainfall is low and erratic, and soils are poor.

But raising farm production in these areas through traditional crop improvement methods has been difficult. Farmers found that the 'improved' varieties produced from many years of commodity-based, top-down, centralized, and technology-driven research just didn't have the characteristics they wanted and didn't work in the conditions they actually faced. Participatory plant breeding (PPB) changes all this by involving farmers in choosing varieties that do have what they want and that work well in their own particular environment.

Farmers select varieties for marginal environments

Public and private plant breeding programs routinely select lines adapted for a wide range of conditions and discard lines that perform well only in poor conditions. Yet some of these lines would be ideal for farmers in marginal areas. Direct selection by farmers in the target environments lets farmers choose what works on their own farm even if it doesn't work in another, taking advantage of what's known as genotype location interaction.

Participatory plant breeding is now very much 'the' way of working with farmers in marginal rainfall environments. ICARDA and partners are working this way in programs to improve a range of crops such as barley, durum and bread wheat, and food legumes, in Algeria, Egypt, Eritrea, and Jordan. Since 2007, the program has expanded to Garmsar and Kermanshah, in Iran. In Eritrea, ICARDA and partners are also working on hanfets, a wheat–barley mixture that gives more reliable yields than pure wheat or barley.

In each country, the success has been repeated, and in each project, the researchers have noted that farmers become empowered by their involvement. They gain the confidence to make decisions on crosses as well as to make suggestions to researchers on factors such as plot size and the number of locations to be tested. What also emerged was that it is important to make sure that women participate too, as women's criteria for making choices often differ from the men's.

Farmer-led barley field trials

In dry parts of Africa and Asia, farmers graze their flocks on several millions hectares of barley stubble. But sheep prefer soft straw, so it's important to plant the right type of barley. Plant breeders usually don't take this into account, being more interested in grain yield. But farmers do, because the straw is important for feeding sheep, especially in dry years.

In 2007, farmers taking part in the Syrian participatory barley breeding program in Kherbet El Dieb worried about the poor palatability of 'Furat 3', a new variety. They decided that grazing trials were needed to assess how sheep took to the new varieties. So, they took the initiative to do their own – a trial involving a flock of 10 sheep and two farmers.

This farmer-led trial helped incorporate straw palatability into the barley-breeding program and shows the importance of considering farmers' needs when improving crop varieties.

Farmers assessed how palatable barley straw is to their sheep – and they now evaluate this factor in participatory breeding trials

Farmers harvest, thresh and weigh grain from experimental plots to measure yields

"Participatory plant breeding is a step on the way to helping poor communities in fragile ecosystems manage the unpredictability of their environment"

Varieties selected by farmers prove their worth in the 2007 drought

Participatory plant breeding is a step on the way to helping poor communities in fragile ecosystems manage the unpredictability of their environment. Even in the widespread drought of 2007 that affected Iran, Iraq, Jordan, Syria, and parts of Turkey, the varieties that ICARDA and farmers selected through participatory plant breeding gave economically acceptable yields – at a time when other farmers growing traditional varieties lost nearly all their barley crop.

A good example is one outstanding line identified during the participatory plant-breeding project in Syria. This was a cross between a line extracted from a Syrian landrace and *Hordeum spontaneum*. Over three cropping seasons, in 12 trials by farmers in Bari Sharky, Hama province, where rainfall in 2005, 2006 and 2007 was just 238 mm, 235 mm and 212 mm, the line out-yielded both the local landrace, 'Arabi Abiad', and the improved variety, 'Furat 2', by 38% and 28% respectively. Farmers gave the new line high scores: 29% higher than two checks over the entire testing period.

International public goods picked up by developed countries

The idea of participatory plant breeding is being picked up in developed countries. This is a good example of how an international public good (not a variety, but a methodology) developed through ICARDA's research is spreading and having an impact well beyond the dry regions. In this case, the North is adopting methods developed and tested in the South.

Farmers and researchers discuss ways of selecting barley varieties

A member of a farming family enters data from field experiments in a spreadsheet that will be e-mailed to scientists for statistical analysis

Partners

Centre for Sustainable Development, Iran
Agricultural Research and Education Organization, Iran
CGIAR Water and Food Challenge Program
Dryland Research Sub-Institute, Iran
Provincial Jihad Agriculture Organization, Iran
National Agricultural Research Institute, Eritrea
Hamelmalo College of Agriculture, Eritrea

Innovative participatory research on natural resources: the best of both worlds

Overview

In the upper reaches of river basins in arid and semi-arid areas, improving rural livelihoods through conventional research methods has been difficult. This is partly because the agro-ecological systems in dry mountain areas and watersheds are complex and varied.

To make livelihoods more resilient and improve natural resource management in these areas, ICARDA is leading a shift from conventional research and a focus on research outcomes to innovative research based on participatory, multi-stakeholder processes. Participatory technology development (PTD) puts people first, in an integrated approach that combines crop and resource management, plant breeding, and socio-economic factors.

An integrated approach

Under the umbrella of the CGIAR Challenge Program on Water and Food, ICARDA and a number of partners are taking a participatory technology development (PTD) approach in the Karkheh River Basin, Iran.

In the Karkheh Basin, rural people are poor, the land is degraded, and agricultural production is low. Farmers grow wheat and barley on three-quarters of the cultivated area. Only 10% is irrigated, while the other 90% relies on the low and often erratic rainfall. So, making livelihoods more resilient and improving natural resource management are high priorities.

An overall participatory technology development framework is bringing together the needs and interests of the farming communities and the expertise and interests of various other key players. These include national and international scientists, extension workers, local NGOs, and integrated watershed management and participatory plant breeding programs.

Adaptability is the key

Adaptability is at the heart of the participatory technology development process. Rather than asking farmers to adapt their ways of working to the crops or technologies researchers develop, farmers themselves choose and try out innovations that they think are best suited to their own way of working and their environment.

Experimenting with adaptability is the main reason why the participatory technology development approach helps both experts and farmers learn. In Iran, the realization that different needs require different solutions led to eight villages coming up with fifteen different options for better and more resilient livelihoods and better management of resources. The options ranged from introducing potato as a substitute for sugar beet to transforming illegal cultivation of shallot on rangelands to a legal farm crop.

In each village, the search for options was driven by the outcomes of participatory problem identification and needs assessments. Farmers had to be able to relate to, take up and adjust the new options as they saw fit. The options had to 'be simple to understand', 'not require changes in major parts of the existing farming system', and 'rely on few external inputs and labor resources'.

From field days to seeing what works for other farmers

Field days are a traditional way of showing farmers the results of research on experimental stations. But, at field days, what tends to happen is that farmers merely inspect experimental plots of new varieties and technologies. There also tends to be a focus on the crop and ways to grow it rather than on the environment – both biophysical and socioeconomic – in which farmers actually grow the crop.

The participatory technology development process is starting to change this. Research teams, rather than holding field days, are arranging for farmers to visit other farmers who have chosen to test out new technologies or crop varieties on their own farms. Technology cross visits, as they are known, not only help promote new technologies among farmers but also give researchers valuable insights.

At these events, researchers encourage farmers to openly discuss pros and cons and give critical feedback on, for example, growing mushrooms for extra income. Seeing, analyzing and

The upper Karkheh River Basin


A technology fair brings new options to the heart of a community

discussing possible outcomes and obstacles together, and genuine interest in each other's experiences and priorities, provide a fruitful learning experience for both farmers and researchers. For example, during one cross visit, the researchers were approached by female farmers, who then were invited to join the next season's trials.

In the main, the host farmers are trying new technologies and varieties because they are truly attracted, not because they are being paid or given subsidies – as has often been the case previously. Dispensing with incentives means that farmers are likely to choose to try options that they think will benefit them. Plus, any changes in the way they do things have more chance of lasting rather than being abandoned when the incentive runs out.

Natural resource management technology fairs

Researchers applied the participatory technology development approach to natural resource management in another innovative way – technology fairs. ICARDA arranged for Iranian participatory technology development partners to join a natural resource management technology fair in Syria. On coming home, the Iranian partners enthusiastically took on board ideas from the fair and promptly organized their own fairs and followed up with needs assessments for four communities in each of the two benchmark research watersheds in the Karkheh Basin. Then, armed with these lists of wants, they put on their own fairs to 'show, tell and discuss' with communities options that might address some of their problems. One example was how to select different fertilizers and adjust application rates based on different crops and soil conditions. Because the fairs were organized in the communities themselves, in a school, mosque or park, they were accessible to men, women and young people.

Farmers as partners

ICARDA no longer sees farmers and rural communities as passive recipients of research results but as competent partners in the research-for-development process. But changing the way research is done is a long-term process. In Iran, participatory approaches are beginning to arouse interest. There is still a long way to go, but participatory technology development sets promising directions.

Participatory technology development is a valuable approach to working with communities on technological change. The technology options themselves are less important than the process of analyzing problems, seeking appropriate and relevant options and solutions, and gradually handing over this process to communities themselves.

> “Farmers play the key role in relating to, adjusting, and adopting new technology options”

Partners
Agricultural Extension, Education and Research Organization, Iran
Jihad-e-Agriculture Organization, Iran
CGIAR Challenge Program on Water and Food

Better livelihoods and more efficient water use, from greenhouses

Overview

Protected agriculture is a double-edged sword on the Arabian Peninsula. On the one hand, greenhouses protect crops from harsh, dry air and allow both water and land to be used efficiently. On the other, farmers need to find the funds to set them up, and they have to cope with the fact that the humid conditions inside can provide breeding grounds for pests and diseases.

To tackle these problems, ICARDA's Arabian Peninsula Regional Program (APRP) has identified and tested improved and affordable greenhouse techniques. In Yemen, the poorest of the Arabian countries, where 79% of the total population live and farm on mountain terraces, grants were provided for plastic houses. This enabled farmers to make the most of small patches of land – switching from subsistence farming to cash crops like cucumbers and tomatoes. Training at farmer field schools has ensured that farmers have adopted integrated production and protection management (IPPM) techniques, to maximize their long-term yields.

In Oman, an on-farm trial has demonstrated the potential for using hydroponics (growing plants without soil) in overcoming problems of soil salinity elsewhere in the Arabian Peninsula. All trials brought farming improvements through increased productivity, reduced water and land use, and the introduction of high-value crops, fetching a premium at market.

Reviving food crops in Yemen

Mountain terraces in Yemen offer little scope for farmers. Land is limited, water is scarce, and technical support is lacking. Because of this, agricultural production and incomes are low and families have been leaving the area in search of a better life in urban areas.

To help revive Yemen's upland agriculture, ICARDA-APRP has been collaborating with Yemen's government. During 2001 and 2002, the partnership provided grants to set up three plastic houses, constructed using local materials, to three villages. Each was set up in a farmer's field, and cucumbers were introduced as a cash crop and sold at local markets. Cost–benefit analysis revealed that the total cost of the greenhouses could be recovered in three growing seasons, if farmers managed their crops wisely.

Greenhouse cash crops could help stem migration to the cities

Based on the success of the pilot project, the French/Yemen Food Aid Program provided ICARDA-APRP with two years of funding to develop cash crop cultivation in greenhouses in the Taez area. Local teams, including agricultural engineers and technicians, set up greenhouses on 35 holdings and planted cash crops including cucumbers and tomatoes. The teams themselves were trained by ICARDA staff and consultants in protected agriculture techniques, and in integrated production and protection management in particular. These techniques were passed onto farmers through on-the-job training, supplemented by five handouts published in Arabic.

It is now two years since the Taez project began and, for the farmers involved, the effects have been dramatic. Overall, in the greenhouses, water efficiency has increased by 40–45%, cucumber yields are 10 times greater, and tomato yields 4.4 times greater than in open fields. Plus, the cropping seasons have increased to two or three a year, instead of the one that was possible in the open field.

By using integrated production and protection management techniques, growers were able to reduce the spraying of chemicals to just 1–3 times a season, instead of the 26 sprays per season previously applied. And, by diversifying their holdings to include high-value crops, farmers have been able to bring home a regular profit for their families.

Growing plants without soil

But protected agriculture is not always successful. In many parts of the Arabian Peninsula, greenhouses are losing their productivity because salt is accumulating in the soil. To tackle this, ICARDA-APRP collaborated with the national agricultural stations of seven countries to develop a protected hydroponics system that allows producers to grow crops without soil. Various hydroponic systems growing cash crops, including cucumbers, tomatoes and strawberries, were tested at research stations in Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates.

The techniques identified at the research centers are now being tested on farms in the region. So far, a trial at a farm in Oman has shown promising results. At the farm, owned and managed by local farmer Abdulla Farsi, an ICARDA-led team designed and erected a hydroponics system to fit in three existing greenhouses, which covered a total area of 2160 square meters. The system was planted with cucumbers, but could be used for other cash crops, enabling year-round use.

The hydroponics system has led to large savings of water, and bigger profits for Mr Farsi. Over five growing seasons, he generated OR15,444 (US$40,138) net profit from growing cucumbers in his greenhouses. He found that his plants were much healthier with virtually no wilting, compared with 40–70% wilting that occurred when they were grown in soil. He also used less fertilizer and pesticides and was able to harvest high-quality produce.

Greenhouse cucumbers are popular with consumers

“Cucumber yields are 10 times greater and tomato yields 4.4 times greater in greenhouses than in open fields”

Hydroponics increases yield and quality on the Al-Farsi farm in Oman

Making an impact

The greenhouse experiments in Yemen and Oman show that, if farmers are trained in integrated and appropriate management techniques, protected agriculture can be a real step forward for farmers in the Arabian Peninsula.

This research is helping to achieve the targets of the ICARDA Research Programs 'Integrated Water and Land Management' and 'Diversification and Sustainable Intensification of Production Systems'. It includes developing and promoting techniques for efficient use of water and land, and identifying new sources of income for farmers through high-value cash crops.

By collaborating with government ministries and agricultural research centers, the ICARDA team provided examples of best practice in intensified, productive and integrated systems and got farmers involved through training in farmer field schools. Diversifying into greenhouses offers great opportunities, can cut down the risks posed by climate change, and provides an economic cushion for local people.

Partners

Ministry of Agriculture and Irrigation, Yemen
Agricultural Research and Extension Authority, Yemen
French/Yemen Food Aid Program
Ministry of Agriculture, Oman
Arab Fund for Economic and Social Development
International Fund for Agricultural Development
OPEC Fund for International Development

Low-cost greenhouse frames are made locally, and can be erected quickly

Value addition to improve livelihoods in Afghanistan

Overview

In the highlands of Afghanistan, local crop varieties give low yields and often succumb to disease. Livestock is vital to most poor rural households, but husbandry is out-dated and processing inefficient and time-consuming. Boosting productivity and making farming more diverse would improve household food security and incomes, so ICARDA is working to do exactly that.

Work by ICARDA and its partners identified the best improved varieties of wheat, rice, mung bean and potatoes that did well in the highlands. As a result, farmers can now get yields 40–60% higher than they could before. Sustainable village-based enterprises were also created to supply improved seed on an on-going basis. So far, these have produced and marketed 980 tons. Plus, ICARDA's introduction of high-yielding mint varieties has transformed this kitchen garden herb into a cash crop, providing a real alternative to opium poppies. The Center is also providing training in mint distillate and mint oil production – an attractive option for income generation among women.

Women from 600 households in 13 villages were also encouraged and empowered to adopt modern smallholder dairying. Interest group meetings to share knowledge and information mean that women learn how improved feeding results in higher milk yields and growth in calf–cow pairs. And, a new churner, introduced by ICARDA, has saved time and effort and boosted butter production.

Training women to use an efficient butter churn

The new churn produces more butter, increasing household incomes

Boosting production of major crops

ICARDA and its partners, including the ministry and other CGIAR centers, conducted variety evaluation trials with wheat, rice, mung bean and potato in Kunar, Laghman and Nangarhar provinces. The researchers then adopted a participatory approach to introduce promising varieties in farmers' fields. Altogether, they ran 315 demonstrations, and encouraged farmers to adopt the new varieties. Farmers increased their yields by 44% with wheat variety 'Lalmi-2', by 60% with rice variety 'Kunduz-1', by 56% with mung bean variety 'MN-94', and by 38% with potato variety 'Kufri Chandramukhi'.

ICARDA has supplied equipment and/or technical assistance to 17 village-based seed enterprises to provide a sustainable seed supply, initially wheat. These enterprises are economically viable and able to produce and market quality seed to local farmers. The most progressive are now diversifying their range of seed to increase and stabilize income.

Mint as a new cash crop

ICARDA has introduced new high-yielding mint varieties in Helmand, Kabul, Kunduz and Nangarhar as a viable alternative to opium production. These, together with technical assistance in production, processing and marketing of mint distillate and mint oil, have made mint an attractive cash crop, especially for women. The number of mint associations doubled from four to eight. And two of these, exclusively for women, are now producing and marketing mint distillate in Kabul and Kunduz.

ICARDA has also trained farmers to produce phenyl and thyme distillates and oil using the same technology, All these distillates and oils have useful medicinal properties, So far, farmers' associations have produced and sold more than 120,000 bottles of herbal distillates.

Empowering women through smallholder dairy farming

ICARDA is promoting modern smallholder dairying among rural women in Baghlan province by helping them form interest groups to share knowledge and information about improved feeding and milk processing methods. Topics covered include feeding of cow–calf pairs, hygienic milking, and efficient milk processing. Women employed by the project organize group discussions and field days – in June 2007, over 500 women attended field days in four villages.

Women are learning about the importance of good nutrition in milk production and calf growth. Winter-feeding – a basal diet of wheat or barley straw with widely varying amounts of protein-rich cotton or flax seedcake, alfalfa and berseem hay, and mung bean straw – is especially crucial. As feed makes up 50–70% of production costs, it's important to use the right amount of supplements to reduce costs and maximize profits. Women's groups participated in two on-farm trials and learned about the methods used.

Researchers first compared supplements for cow-calf pairs fed a basal winter diet of wheat straw. Berseem hay was the best supplement, increasing average milk yield by 17% and total daily weight gain of cow–calf pairs by 28% more than either alfalfa hay or mung bean straw. They then compared three levels of flax cake supplement fed to cow–calf pairs grazing native pasture in summer. Adding flax cake to the diet increased daily weight gain by 34%. Weight gains in animals given 3 or 4 kg of flax cake each day was about 30% more than those given 2 kg.

Farmers inspect trials of more productive varieties of potato

The new butter churn is very popular with households

Based on these studies, the best options for smallholders are to feed a basal winter diet of wheat straw plus berseem hay, and to feed 3 kg of flax cake when grazing native pastures in summer.

The project is also promoting an easy-to-use, hand-operated butter churner that reduces the daily churning time from over 3 hours to less than one hour. Teenagers can use it easily, and it produces 22% more butter from the same amount of yogurt than the traditional churner.

"An important aspect of this project is the empowerment of rural women"

Partners

Ministry of Agriculture, Irrigation and Livestock, Afghanistan
Ministry of Women's Affairs, Afghanistan
CIMMYT - International Maize and Wheat Improvement Center
International Rice Research Institute
World Vegetable Center
International Potato Center
United States Agency for International Development
Department for International Development, UK

Linking poor communities to markets

Overview

Lack of access to markets is often an important factor in rural poverty. Investigating ways of making rural market chains work better is therefore a critical component of the social, economic and policy research that ICARDA and its partners undertake to improve livelihoods in rural communities.

ICARDA's partners in Morocco have, for example, identified a lack of access to markets as a major factor holding back rural development in the High Atlas, south of Marrakech. As part of a more extensive research-for-development project to improve agricultural production systems in mountain regions, ICARDA researchers and their Moroccan partners therefore set out to investigate how market chains in these communities work and what can be done to improve them.

The research showed that although roads and other infrastructure are important and can help farmers get their produce to market, the infrastructure alone is not enough. What is important, if farmers and communities are to move away from subsistence farming and climb out of poverty, are the right kind of institutions to help them sell their produce in national and international, as well as local markets.

Assessment of market chains

Researchers surveyed households in two valley communities (Taddarine and Anougal) in very similar environments in the High Atlas. The main difference in infrastructure between the valleys is that Taddarine has a paved road and electricity and Anougal hasn't. For the main agricultural products, researchers then undertook a market chain assessment using participatory market chain analysis methods. This was designed to determine how infrastructure and marketing institutions differed between the two valleys.

Good infrastructure makes a difference

The road to Taddarine has been paved since 1964, so large-scale traders can drive up the valley in their large trucks and buy directly from farmers. As a result, farmers benefit from the competition between traders because it drives up prices. Anougal, on the other hand, has no paved road, which cuts the community off and makes it more difficult for farmers to get their produce to market. Here, small traders have a monopoly, as their lorries are the only vehicles that can negotiate the dirt road. This means that farmers get paid less because fewer traders are competing to buy their crops.

Remote mountain communities have difficulty marketing what they produce

A comparison of apple production in the two communities shows just how much difference having a paved road makes. Apples have been grown in Taddarine since 1974, and by 2004 the valley was producing around 1,200 tons a year. However, apples only began to be grown in Anougal in the 1990s because neither traders nor extension workers could get there easily. Apple production hasn't really taken off because farmers can't get their apples to market. As a result, Anougal is still only producing 160 tons a year: nowhere near as much as Taddarine.

Cooperatives can play a crucial role

The research also showed that local institutions can play a crucial role in opening markets up to small farmers and reducing rural poverty even when infrastructure is poor. In the Taddarine valley, where there is a paved road and electricity, 70% of households were classed as 'poor' or 'extremely poor'. In the Anougal valley, however, with neither a paved road nor electricity, only 57% of households were 'poor' or 'extremely poor'. The reason why there is less poverty in Anougal is because a dairy cooperative has been set up which links small farmers to a milk processing factory and gives them access to a reliable market for their milk.

This dairy cooperative is a good example of a community institution that can link poorer households to the market economy even when infrastructure is poor. In this case the cooperative collects, cools and sells milk to a collection center. Milk marketed through the cooperative has risen from 1800 liters per year in 1993 to 30,000 liters per year in 2004.

What this makes clear is that helping small producers to organize themselves into cooperatives is a way of helping them become part of the market economy and lifting them out of poverty. Well-managed cooperatives, with appropriate support, can give rural communities access to markets even in remote areas. ICARDA is now working to test out community approaches to supporting the establishment of such institutions.

Value chains and quality control

Quality is another important aspect of marketing. Small farmers tend to go for large harvests, irrespective of quality. But research shows that smaller quantities of high quality produce are far more profitable than large quantities of poor quality fruit.

In Anougal, for example, most of the apples are sold off the tree four or five months before harvest. While this means farmers get paid in advance, it also means they are often not paid as much as they could be – as they depend on traders to estimate the quantity and quality of apples that will eventually be harvested. In Taddarine, quite the opposite happens. Farmers sell very few apples direct from the tree. They pick the crop, sell the low quality fruit locally and store the rest for a couple of months. The apples ripen in store and when they are sold to traders they fetch four to five times as much as the poor fruit. Quality pays.

ICARDA's research shows that to get the maximum income from their crop, farmers are better off storing apples in coolers and spreading sales over the season. Selling the crop on the tree is the least profitable option. The reason farmers sell apples straight off the tree is because they have cash-flow problems and can't get loans from banks, so they rely on informal and often expensive credit arrangements instead. So, setting up institutions that would provide them with loans to help them manage their cash flow, like micro-credit services for example, could help them through cash-poor periods.

Quality control means farmers get better prices

> "Infrastructure such as electricity, paved roads and regular public transport is not enough to improve the livelihoods of poor people living in remote areas"

Next steps

Farmers and rural communities need help to set up institutions, such as effective cooperatives and micro-credit services, which will give them better access to markets. Governments, civil society organizations and NARS can provide this kind of support. The private sector can also play a major role, by helping farmers learn how to add value to their products. Helping farmers become part of market chains – from the local to the global – will improve their livelihoods and reduce rural poverty.

The participatory market chain approach brings stakeholders in market chains together to stimulate action and cooperation. The involvement of these stakeholders is crucial if farmers and communities in remote mountain regions are to move away from subsistence farming and rise out of poverty.

Partners

Swiss Development Cooperation
Institut National de la Recherche Agronomique, Morocco
International Fund for Agricultural Development

Preserving drylands and boosting incomes from goats and sheep: first steps in Mexico

Overview

One-sixth of the world's population lives in dryland areas – fragile ecosystems with low and irregular rainfall. Smallholder farmers in these areas typically raise both crops and small ruminants, such as goats and sheep. But, with land degradation spreading in many areas due to over-grazing and changes in rainfall and climate patterns, dryland pastures have become difficult to manage.

ICARDA is therefore working with farmers in various parts of the world to maximize the productivity of their livestock while protecting these vulnerable lands. ICARDA's assistance ranges from sophisticated scientific studies to working with farmers on the most pressing problems they face.

As part of this work, ICARDA teamed up with researchers and farmers in Zacatecas, Mexico, to improve the production of small ruminants in dry areas. After finding out what farmers saw as their main problems and the main factors they considered were holding them back, the research project took a step-by-step approach to improving productivity and preventing land degradation, and, at the same time, orienting products towards markets.

Towards sustainable improvements in small ruminant production in drylands

Mixed cropping systems and small ruminant production are an important source of food and income in arid and semi-arid regions of Mexico. In Zacatecas state, for example, an estimated 7600 families rely on goat production, while another 7000 depend on mixed crop-and-sheep systems. Much of this production takes place on *ejidos*, communal agricultural lands that were established under the country's agrarian reform of the early 20th century. Unfortunately, however, unrestricted grazing has badly degraded much of this land.

In 2004, therefore, ICARDA teamed up with Mexico's National Institute for Agriculture, Forestry and Livestock Research (INIFAP) for a series of studies funded by the International Fund for Agricultural Development (IFAD). The aim was to set the stage for improving small ruminant production systems. The project began with three studies in the Panuco area of Zacatecas state that aimed to determine appropriate land uses and production systems.

Overgrazing and land degradation threaten livelihoods in Zacatecas state, Mexico; scientific inputs from ICARDA and its partners are helping to tackle the problems from different angles

Creating a map of areas suitable for goat production

The first study aimed to find out which areas were suitable for goat production. Researchers used geographic information systems technology, the agroecological map of Zacatecas, and the association between the availability of forage and the current distribution of goats across the state, to create a map that classifies areas by their capacity to provide feed for goats. The map pinpoints the zones suitable for goat and sheep production in all municipalities of Zacatecas. The map also helps in identifying areas where there is potential to introduce new technologies that improve productivity and natural resources. This makes it a valuable tool for planning across the state, particularly for extension and development agencies, as it shows where improving goat productivity will be most worthwhile.

The map showed that the study area in Panuco is a 'good' area for goat production, a finding that confirms that the goat component in its current production system is appropriate

Identifying agricultural land that should revert to rangeland

The second study identified agricultural land that would be best taken out of cultivation and managed as rangelands. To do this, researchers analyzed the soils, vegetation and hydrology in the project area. Their geostatistical analyses of these variables resulted in a series of maps that classify areas according to how suitable they are for reconversion to rangelands. These maps that apply to the *ejido* level will also be invaluable in government planning to improve *ejidos* throughout the country.

In the Panuco *ejido*, for instance, the mapping project revealed that one-third of the 2444 hectares currently cultivated is really only suitable for rangeland use. In these areas, restoring rangeland vegetation – by planting cactus, forage cereals and legumes such as vetches and *Lathyrus*, for example – could make sheep and goat production more productive as well as cut down soil erosion.

Identifying areas prone to soil erosion

The third study towards improving dryland productivity identified the areas most prone to soil erosion. To do this, researchers monitored erosion in areas of native vegetation, first where the density of cacti was high and second where there was a medium cover of native thorny shrubs. They also monitored erosion in two grazing systems, one rotational and one unrestricted. What they found was that erosion and runoff were less where the density of vegetation was high and where farmers practiced rotational grazing. This information, when combined on a map, highlighted areas prone to soil erosion.

Goats and sheep, when allowed to graze freely, degrade native vegetation, which in turn leads to runoff and soil erosion. Rotational grazing systems and plantings of species that not only provide browse for animals but also cover the ground more densely with vegetation, could reduce erosion and runoff substantially.

Improving rangeland productivity

These three studies set the stage for testing out better grazing systems to help small sheep and goat farmers enhance productivity and halt land degradation, by grazing rangelands in rotation for example. At the site where a grazing rotation was tested, researchers found that rainwater did not run off so quickly and was used more efficiently than at sites where grazing was continuous. The vegetation cover was also better and the yield of biomass higher. These results allowed researchers to quantify the effects of grazing on range productivity. This information can be used to design changes in the production system and to estimate the need to provide animals with feed supplements. The study's results have already been used to implement, with farmers, a number of new activities designed to improve feeding systems.

Targeting production systems at market opportunities

Knowledge derived from the results of these studies can be used to design changes in production systems and quickly estimate animal-feed-supplement needs over large areas, in order to target market opportunities. A good example is to move from a system which mainly produces meat to systems which produce dairy products or a mix of products such as suckling kids plus dairy products.

Such systems have the added advantage of integrating women into production systems, as it's the women who take care of young animals and do much of the processing of dairy products. These possibilities were considered carefully by the project; in response, it developed a community milk-production plant. This plant is owned and managed by women from the community, and is already up and running. The women in Panuco are now making cheese and selling it through a local supermarket chain in the state capital, Zacatecas city.

On a broader level, the results of these studies can be applied in other states in Mexico, and other similar agroecological regions, to ensure land is protected, even as it becomes more productive and improves the livelihoods of local communities.

Research is helping farmers to use dryland pastures more sustainably and to switch to profitable dairy production: women in the Panuco project site in Mexico are already selling community-made cheese to supermarkets

> "The results can be applied to ensure land is protected, even as it becomes more productive and improves the livelihoods of local communities"

Partners

National Institute for Agriculture, Forestry and Livestock Research, Mexico
International Fund for Agricultural Development

More crop per drop: irrigation practices to optimize use of scarce water

Overview

Water scarcity, land degradation, population growth and climate change pose huge challenges for dry regions. Fifteen countries in northern and southern Africa and West Asia already have the lowest per capita water resources globally, for example. Plus, a growing demand for water from homes and industry means that in the dry areas, agriculture's share of water, currently around three-quarters of the total amount used, will shrink.

What this means is that farmers are going to have to produce more with less water, boosting water productivity in both rainfed and irrigated agriculture and producing more 'crop per drop'. Improving agricultural returns per unit of water is therefore a vital component of ICARDA's strategy to combat poverty and promote economic development.

As part of this, a major new ICARDA project is exploring ways to improve water productivity, through more efficient irrigation and other options, in rainfed and irrigated areas in Central Asia. Low-cost techniques, such as mulching and raised beds, are being used to improve water productivity. We are also exploring ways in which wastewater can be used productively, turning it into an economic asset instead of an environmental problem.

More crop per drop: diverse strategies for diverse environments

There's no 'one size fits all' solution to helping farmers produce more while using less water. In Central Asia, therefore, ICARDA is working with partners to develop options and adapt techniques for improving water-use efficiency and land management. The lessons learned in this process are being synthesized to produce international public goods, which can be applied (with relatively minor adaptations) to similar agro-ecologies in other parts of the world.

In Azerbaijan, for example, we have studied how drip irrigation can be used to improve water productivity (the yield per unit of water used). It was possible to cut water use by nearly half while improving the effectiveness of fertilizers. And in Kazakhstan, we have found that replacing conventional planting and strip irrigation with raised beds and deficit supplemental irrigation improves water use efficiency and gives higher yields of winter wheat.

Chute irrigation is a low-cost way of using less water and boosting crop yields

ICARDA and national partners have investigated better ways of irrigating a range of crops, producing international public goods that can be applied in other parts of the world with similar agro-ecologies

In Tajikistan, researchers have used mulches of hay, grape prunings and manure to conserve soil moisture. They have also introduced strip cropping and continuous cropping instead of fallow – both of which reduce erosion. And in Turkmenistan, ICARDA and its partners are exploring and optimizing low-cost irrigation methods to improve the efficiency of irrigation systems. One such method is sprinkler irrigation, which uses considerably less water than traditional furrow irrigation, without a drop in yields. Other examples include the work done in Uzbekistan, where chutes and contour irrigation of winter wheat have been found to use less water and increase yields. For example, in on-farm trials conducted in Tashkent province, contour irrigation gave grain yields nearly 20% higher – and irrigation water-use efficiency over 44% higher – than conventional irrigation.

Key to these results were the efforts made to combine ICARDA's global experience with the understanding that national research institutions have of local conditions. This has resulted in a range of options and strategies for more efficient use of water in many different environments.

Wastewater: from environmental problem to important resource

Millions of small-scale farmers in the urban and peri-urban areas of developing countries use wastewater to grow crops. In fact, sometimes they actually prefer to use it because it contains more nutrients than freshwater. Other times they have no alternative. But, as well as nutrients, wastewater may also contain other substances not so good for human health or the environment. So what is needed are safe ways of using wastewater productively, because treated, untreated and partly treated wastewater are all becoming more and more important for crop production in dry regions.

Another issue is the fact that more wastewater is being produced as populations increase, urban areas expand, living standards rise, and economies grow. Rather than turning into an environmental problem, this wastewater can be put to safe and productive use. In fact, by using wastewater, small-scale farmers will be better off because supplies of wastewater are reliable, and aren't dependent on rainfall. Wastewater may also be cheaper than getting water from elsewhere, as pumping groundwater, for example, can be expensive. And broad stakeholder participation ensures that the health, environmental, social and economic issues associated with using wastewater are taken into account. The result of judicious use of all possible water resources will be higher water productivity and incomes in resource-poor communities.

ICARDA has been studying the potential of wastewater for crop production for some time. A five-year study in Almaty, Kazakhstan, for example, has shown that treated wastewater from the city did not harm trees grown with it – poplar, ash, mulberry, quince and dog rose. In fact, irrigation with wastewater raised the availability of nutrients without contaminating the soil with heavy metals. Researchers are now growing fodder for animals, also irrigated with wastewater, between the trees, and studies are under way to determine whether animals suffer any harmful effects from fodder grown this way.

Treated urban wastewater has nutrients that fertilize tree crops but do not harm the soil

> "The need to improve water use in agriculture is not only vital for agricultural productivity but also for ecosystem health in dry areas"
>
> (ICARDA Strategic Plan 2007–2016)

Partners

Research Institute of Soil Erosion and Irrigation, Azerbaijan
Research Center of Soil Science and Agricultural Chemistry, Kazakhstan
National Water Management Institute, Kazakhstan
Research Institute of Soil Sciences, Tajikistan
Turkmen Agricultural University, Turkmenistan
Central Asian Research Institute of Irrigation, Uzbekistan
Asian Development Bank

Harvesting rainwater to improve dry rangeland ecosystems

Overview

When water is scarce every drop is precious. But a lot of rain in dry regions often falls during heavy storms and just runs off the hard dry land. Not only is this rainwater lost to farmers, it also erodes soil and carries it away. But this doesn't have to be the case. Simple structures that trap rainwater and soil can make use of water that would otherwise be lost, to improve grazing on vast areas of rangelands for example. ICARDA's research shows that substantial increases in water productivity are possible.

In the *Badia* rangelands of Syria and Jordan, ICARDA has taken an integrated approach to improving livelihoods in pastoral communities. This combines low-cost ways of harvesting rainwater with the introduction of plants that will improve grazing for flocks of sheep and goats. Quickly and easily built ridges and furrows along the contours concentrate rainwater runoff, and trap soil and soil moisture. Then, plantations of shrubs that livestock can graze on are grown where the water and soil collect.

A quicker and cheaper way for farmers to harvest water

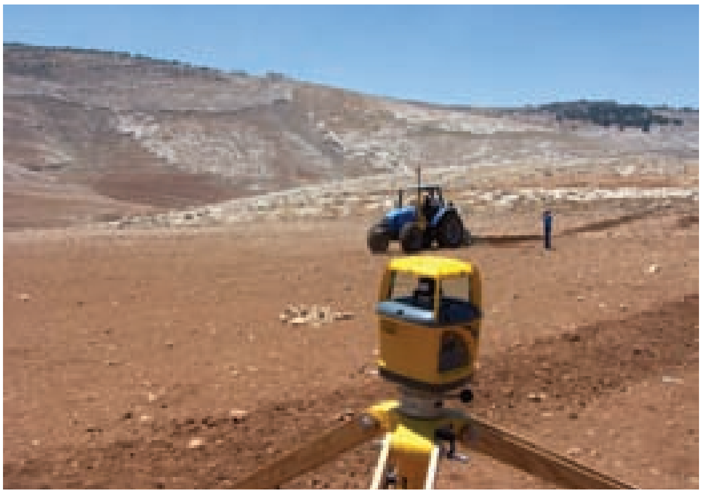
Using water-harvesting techniques, ICARDA and pastoral communities have rehabilitated and re-vegetated thousands of hectares of the low-rainfall degraded *Badia* rangelands in Syria and Jordan. Rainfall, rather than running away, is caught in what are known as 'microcatchments' where it sinks into the ground and increases soil moisture. Shrubs planted in these microcatchments provide grazing for goats and sheep.

Farmers know that water harvesting works well. But, constructing contour bunds for microcatchments is time-consuming and 5 hectares a day is about the most that can be covered by a team of three. What takes so long is surveying and pegging out the paths that tractors should plow. This has to be done by skilled surveyors. Farmers demanded a quicker and cheaper way.

Systems that automatically guide tractors as they plow are ideal for putting in contour bunds but are expensive and complicated. So, researchers took a laser guidance system, used elsewhere for leveling land, and adapted it to provide farmers with a low-cost but high-tech way to plow contour bunds quickly and easily. The system eliminates the need for surveying and pegging. Tractor drivers keep their machines on the contour line using the laser guidance system – a laser transmitter on a tripod, a laser receiver on a mast on the tractor, and a control panel.

Now, one person with just a little training can lay out 15 to 20 hectares a day, three times more than before. What's more, because it's very accurate, rainwater is caught evenly along the catchment.

The new system reduces costs drastically, saves time and effort, and is easy to operate. This is important, because the costs of investing in rangelands where the inherent productivity is low must be carefully weighed against the benefits. It's a system that can be adopted and used throughout the dry regions of West Asia and North Africa.



A simple laser guidance system makes plowing contour bunds cheap, quick, and accurate

Using harvested water to improve grazing

Importantly, ICARDA's participatory work with pastoral communities to rehabilitate rangelands integrates these improvements in water harvesting with improvements in grazing. Because water harvesting means there is more water in the soil, farmers can take advantage of this to improve degraded natural pastures.

Researchers chose two shrubs that are widely used to rehabilitate rangelands and provide good browse for sheep and goats, *Atriplex* and *Salsola*, and planted them in water-harvesting microcatchments. The microcatchments proved very effective in collecting enough rainwater for the shrubs to survive and produce browse for sheep and goats. Over two years, the average survival rate for *Atriplex* and *Salsola* was excellent (83.3%). Plus, they provided a great deal more browse (92.1% more) than degraded native vegetation.

Because the soil in the microcatchments is better and there is more water, the survival rates and growth of *Atriplex* and *Salsola* proved much higher than in similar environments elsewhere in Jordan. Researchers expect the shrubs to be even more productive and provide more animal feed as they mature. They are also studying what other plants could be introduced to re-vegetate sparsely vegetated areas, produce forage, and broaden the plant diversity of rangelands.

Water-harvesting techniques help shrubs to establish themselves and survive – this helps to rehabilitate degraded rangelands and provides feed for local people's animals

Combining resource management and grazing management proves effective

ICARDA's multidisciplinary system-based approach combines resource management and grazing management, an effective mix in combating poverty and promoting economic development. Low-cost water harvesting can improve grazing for pastoral communities even where rainfall is low and soils are poor.

The community approach is important for managing collective resources such as rangelands and water. Better grazing practices prevent degradation and raise the productivity of pastures. Our participatory work with pastoral communities is helping them manage the rehabilitated rangelands and extend water harvesting into other areas.

Goats graze on shrubs growing in bunds that trap rainwater

"The productivity of rangelands, which dominate the dry areas, has declined because of widespread overgrazing. Small-ruminant husbandry, central to farmers' livelihoods, is witnessing a downward spiral of overstocking, leading to land degradation and biodiversity loss, thus further aggravating poverty."

(ICARDA Strategic Plan 2007–2016)

Partners

National Center for Agricultural Research and Extension, Jordan
Faculty of Agriculture, University of Jordan

Developing much-needed tools for managing agroecological diversity

Overview

Dryland areas are some of the least productive agricultural areas in the world. They cover over 40% of the global land area and are home to more than two billion people – including some of the world's poorest.

ICARDA's strategy emphasizes helping poor rural populations to adapt and make their farming systems more resilient to harsh dryland environments. But the agroecologies and agricultural systems in drylands are very diverse. The intricate mosaic of dryland ecosystems means that research findings that work in one place often do not work when transferred to another. So research findings have not been taken up as widely as hoped.

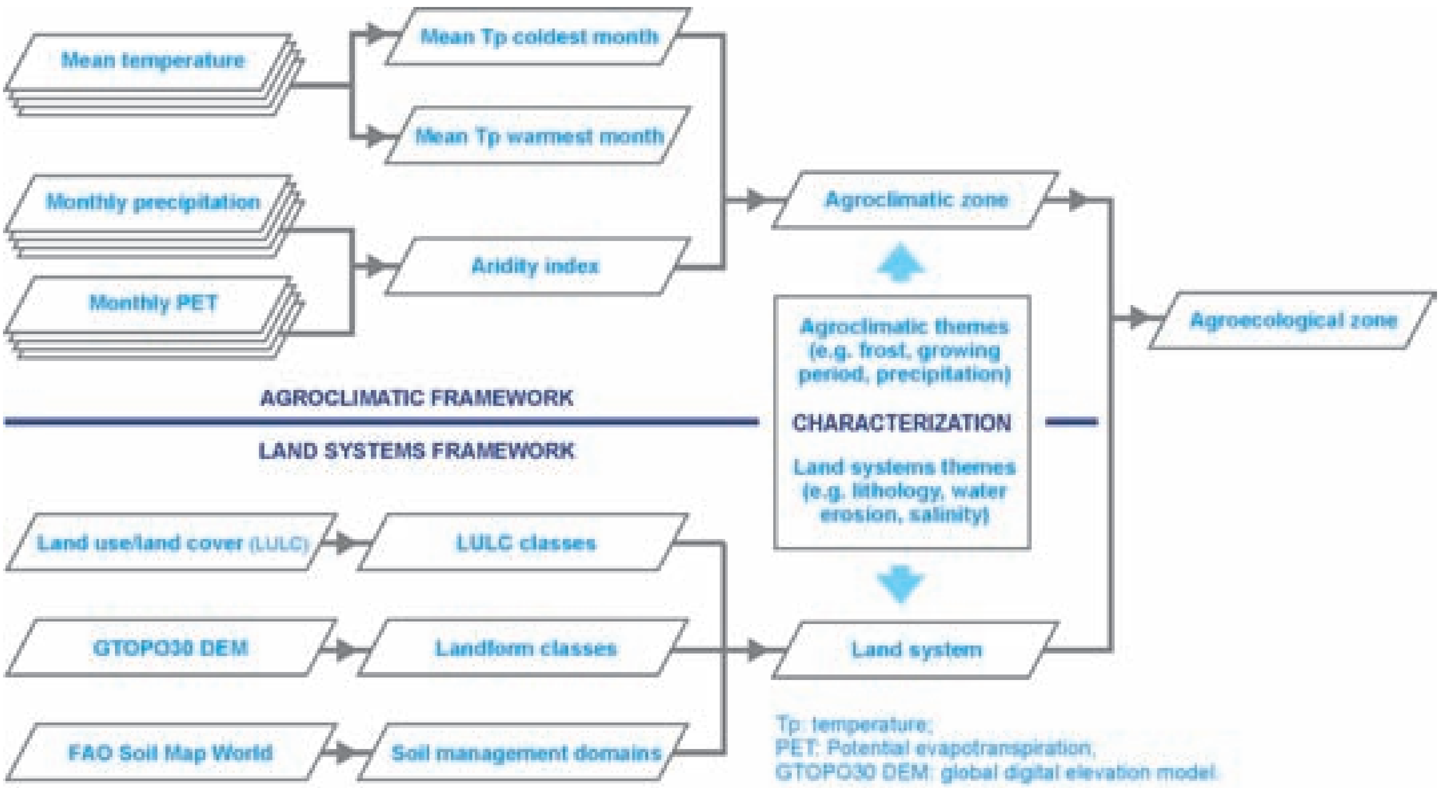
One useful concept for directing solutions to places where they will work is agroecological zoning. Using cutting-edge tools, ICARDA scientists have mapped the agroecological zones in the whole of the CWANA region at a resolution of one kilometer. The method they developed will be invaluable for planning research and developing agricultural policies, for determining the comparative advantages of various areas for different crops, and for managing biodiversity and combating land degradation, for example.

Rapid six-step method for mapping agroecological zones

The world's drylands are extremely diverse, and this has made it very difficult for many farmers to adopt new techniques and crops developed for drylands 'in general'. Put simply, one size does not fit all and solutions need to be tailored to each specific agroecosystem. For example, irrigation, so important in drylands, creates artificial agroecological niches, often very small, where natural conditions and production systems contrast starkly with their surroundings. Adjacent areas may be quite different and suited to quite different crops or cropping systems.

ICARDA researchers have come up with a six-step method for rapidly mapping agroecological zones. Using modeling and geographic information systems, huge sets of data, such as those from remote sensing and weather stations, are combined, sifted and analyzed (Figure 1).

Figure 1. The six-step method developed by ICARDA for rapidly mapping agroecological zones combines agroclimatic and land data.



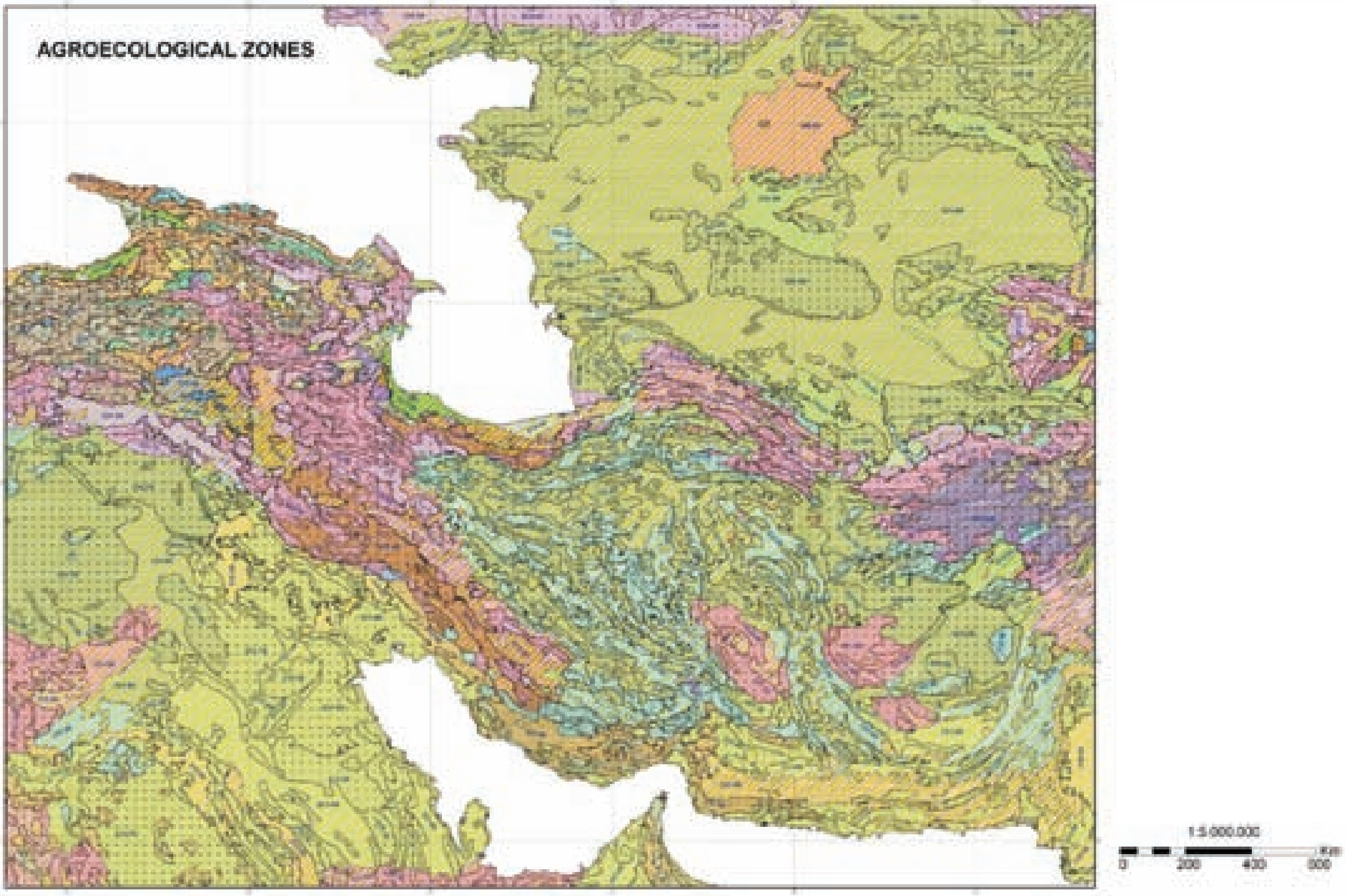


Figure 2. Agroecological zones of Iran and parts of West and Central Asia, the Caucasus and Egypt at a resolution of one kilometer.

The result is a map of agroecological zones (Figure 2). This type of integrated spatial information is particularly important for managing the diversity of agroecological zones in drylands.

The method, developed to map agroecological zones in Central and West Asia and North Africa, can be applied without major modifications at a wide range of scales. The method uses four sets of data – climate, land use/land cover, terrain, and soil. The methodology has already been taken up in Turkey, and in the Karkheh, Aras and Daryacheh-Uromieh river basins in Iran.

Including factors such as geology, surface water and groundwater makes it possible to refine the zones even further. This means that the tool can be tailored to quite detailed applications. It can, for instance, be used to identify agroecological zones susceptible to erosion in order to guide the development of policies to combat land degradation (see box overleaf).

"Agro-ecological zoning has already been taken up in Turkey, and in the Karkheh, Aras and Daryacheh-Uromieh river basins in Iran"

Susceptibility of agroecological zones to erosion in the Karkheh river basin, Iran				
	% of area susceptible			
Agroecological zone	To no or slight erosion	To moderate erosion	To severe erosion	To very severe erosion
Arid, mild winter, warm to very warm summer; irrigated cultivation	90	8	2	0
Semi-arid, cool winter, warm to very warm summer; rainfed cultivation	65	20	10	5
Semi-arid, cool winter, warm to very warm summer; forests on rock outcrops or very shallow soils	30	50	5	15
Semi-arid, cold winter; warm summer; range on rock outcrops or very shallow soils	15	60	15	10
Badlands	5	15	30	50

Making best use of water

Based on their work on agroecological zones and using GIS, remote sensing and modeling, ICARDA researchers have also developed a method to show where supplemental irrigation could be most beneficial.

Irrigating only when necessary (known as supplemental irrigation), rather than irrigating fully, saves water in irrigated areas. One good example is supplemental irrigation on spring-sown and winter-sown chickpeas. This can cut water use by half while boosting and stabilizing productivity.

The savings in water can then be used in rainfed areas to supplement low rainfall. But, it's important to identify where supplemental irrigation can be most useful. Not only does the land need to be suitable, it needs to be fairly flat, and fairly close to the water source so that it is not too expensive to pump or carry the water.

The method developed by researchers to answer this question combines a simple model to work out the water savings that could be made by shifting from fully irrigated spring/summer crops to supplementary irrigated winter/spring crops with a procedure for allocating water to suitable rainfed areas nearby. Based on this, researchers showed, for example, that by shifting from a fully-irrigated summer crop of cotton to a crop of winter wheat with supplemental irrigation, the irrigated area in Syria could be more than doubled without using more water.

The method can be easily applied in other dryland areas by adjusting the factors, decision rules and parameters for determining suitable rainfed areas and priorities for allocating water for local conditions.

All this means that ICARDA's work on agroecological zones is already helping to identify where it would, and would not, be possible to bring more land into production without using more water. The next step is to develop a decision-support tool that will allow planners and policy makers to develop relevant scenarios at different scales and for specific locations.

Partners

Dryland Agricultural Research Institute, Iran
Central Research Institute for Field Crops, Turkey
CGIAR Challenge Program on Water and Food
General Directorate of Agricultural Research, Turkey
Comprehensive Assessment of Water Management in Agriculture

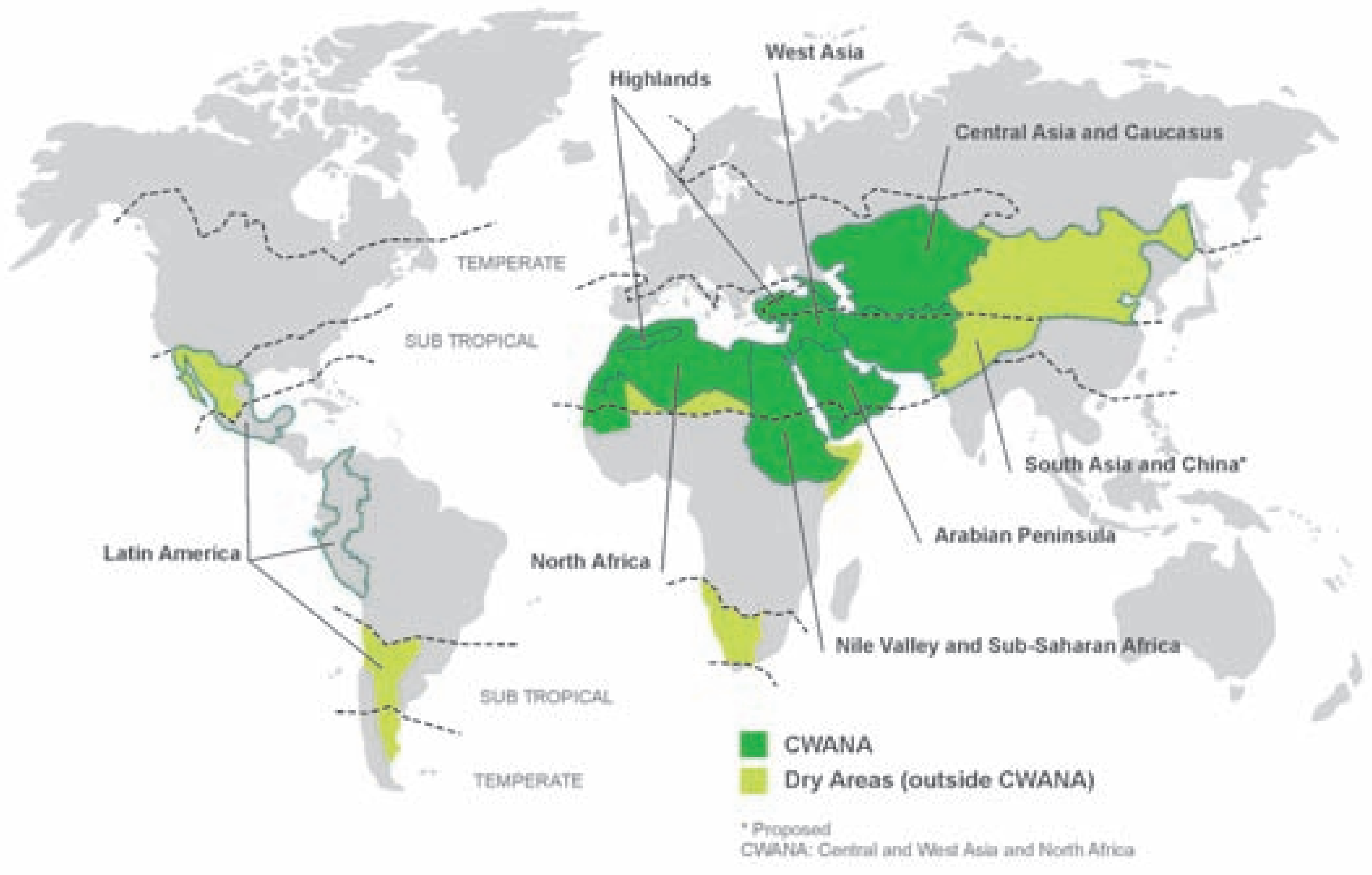
International Cooperation

Decentralized and collaborative research – through cooperative international programs – plays an important role in implementing ICARDA's strategy. The Center's international cooperation programs promote research partnerships, and are platforms for up-scaling and out-scaling research findings. They foster an integrated approach to addressing the challenges faced in dry areas around the world. And, not least, they enhance the capacity of the partner NARS.

Key components of ICARDA's international cooperation programs are their integrated research sites. The Center's early successes in transferring new technologies and options to different environments, through adaptive research, have encouraged it to expand these sites in collaboration with its NARS partners.

Through its integrated research sites, ICARDA catalyzes both North–South and South–South cooperation to link research with development. The impact of the collaborative research ICARDA undertakes with its national partners is measurable – resulting in higher crop productivity, increased food production, and stronger research programs and infrastructure in many countries. Perhaps even more significant, though less easy to measure, is the success ICARDA has had in crossing national boundaries and bringing together researchers from various countries to jointly address common problems of food shortages and human suffering. This is an achievement of which we are justly proud.

ICARDA's Regional Programs



Arabian Peninsula Regional Program

The *Arabian Peninsula Regional Program* organizes and coordinates research, capacity building, and human resource development in water resource management, forage and rangeland management, protected agriculture, and date palm improvement.

The Arabian Peninsula Regional Program (APRP) works in seven countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates and Yemen. Previous APRP projects, supported by the Arab Fund for Economic and Social Development (AFESD), the International Fund for Agricultural Development (IFAD), and the OPEC Fund for International Development (OFID), developed sustainable technologies for improving the production of forage and high value horticultural crops; rehabilitation of rangelands and the management of natural resources in the Arabian Peninsula. New projects aim to enhance rural livelihoods by transferring these technologies to smallholder farmers.

Working with communities

APRP has begun transferring to farmers techniques for the successful production of high value crops in greenhouses and forage from indigenous species, and rangeland rehabilitation. ICARDA in collaboration with national programs, has introduced buffel grass or lebid (*Cenchrus ciliaris*) as high-quality forage with efficient water use. It can be harvested 10 times a year, with dry matter yields of up to 20 tons/ha. Lebid is significantly more water-efficient than Rhodes grass. More than 20 growers have adopted buffel as a fodder crop.

In protected agriculture, the techniques mainly involve hydroponics (soil-less culture) and integrated production and protection management (IPPM). In Oman and Kuwait, farmers are using soil-less techniques to produce high quality cucumbers and strawberries. They obtained significantly higher yields and better quality, and made tremendous savings in water use. IPPM techniques are used by pilot growers in all countries. These techniques helped growers to reduce or eliminate the use of agro-chemicals, to increase yields and quality, as well as to improve water use efficiency.

In Yemen, farmers and local researchers received intensive training in growing cash crops on marginal and non-productive land. Following this two-year project, funded by the Yemen Food Aid Program supported by France, farmers' incomes significantly improved through increased productivity on relatively small areas using only limited amounts of water. In addition, the 40–45% saving in irrigated water could be used to expand the activities of other farmers.

The protected agriculture and IPPM techniques developed by APRP have been so successful that ICARDA has transferred them outside the Arabian Peninsula, to Afghanistan and Pakistan.

Building partnerships

During 2007, APRP enhanced relationships with NARS throughout the Arabian Peninsula. For example, in the Emirates, Ministry of Environment and Water officials met with ICARDA's Director General to discuss joint research on date palm, rangeland agriculture and natural resources management. In Oman, Ministry of Agriculture officials met with ICARDA senior management to discuss expansion of joint research in protected agriculture and rangeland rehabilitation. And in Qatar, government ministers discussed with ICARDA the establishment of an International Center for Protected Agriculture in Dry Areas in Qatar, under the umbrella of the CGIAR.

ICARDA signed a Memorandum of Understanding with Kuwait's Public Authority for Agricultural Affairs and Fish Resources. This agreement outlines areas in which the two organizations will work together.

Planning action and building capacity

Seventeen farmers selected for pilot growing projects, and 11 members of the projects' teams in Yemen received practical training in greenhouse management and IPPM during farmer field schools. Later in the year, researchers, extension workers, officials and all 35 farmers involved in pilot projects in Yemen gathered together at an end-of-season workshop held at Taez. The participants discussed how to further implement protected agriculture techniques developed by APRP.

ICARDA held its 42nd board meeting at the headquarters of AFESD in Kuwait. During the meeting, APRP presented an overview of achievements from 10 years of collaboration in the Arabian Peninsula.

Looking ahead

The achievements of APRP include the technology packages in rangeland rehabilitation, irrigated forages, on-farm water management, and protected agriculture. These packages aim to improve the welfare of poor farmers, natural resources

Yemen's Under Secretary for the Ministry of Agriculture and Irrigation, H.E. Abdul Malek Al Arashi, visits a pilot farm spearheading protected agriculture techniques in Yemen management and the environment. To achieve these goals AFESD, IFAD, and OFID are funding a new APRP program to transfer these technologies to end-users.

During this new five-year program, due to start in mid-2008, ICARDA will continue to seek new horizons for supporting agricultural development and natural resource management in the Arabian Peninsula.

Central Asia and the Caucasus Regional Program

The *Central Asia and the Caucasus Regional Program* establishes strong linkages with the NARS in plant genetic resources, germplasm improvement, soil and water management, integrated feed and livestock production, socioeconomics and policy research, and human resource development.

ICARDA's Central Asia and the Caucasus Regional Program (CACRP) covers Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan in Central Asia, and Armenia, Azerbaijan and Georgia in the Caucasus. The regional office is located in Tashkent, Uzbekistan. In 2007, a sub-regional office was opened in Tbilisi, Georgia, to strengthen activities of the program in the Caucasus.

Working with communities

CACRP and NARS partners organized more than 20 farmers' field days in 2007, in order to disseminate the technologies developed under various projects. More than 400 farmers, extension workers and researchers participated in these field days. The Program also gave out to farmers the 15 guidelines and brochures on innovative technologies produced that year. These guides covered on-farm water and soil management, crop diversification and sustainable agricultural practices.

Smallholder farmers in the region are benefiting from the 14 new varieties of crops based on ICARDA material that were officially released in 2007. To aid the improvement and distribution of seed, the Program has provided NARS partners with equipment such as deep freezers, air conditioners and thermostat controls. It also helped establish two new genebanks in Kazakhstan and Uzbekistan.

CACRP completed two projects testing 50 improved cost-effective technologies for on-farm soil and water management. Scientists are now talking to farmers in the project areas about the best technology options. National programs will take the information further afield.

Other research in 2007 included economic assessments of improved technologies, livelihood surveys, livestock value chain analyses, studies on integrated feed and livestock management, and sustainable land management.

Building partnerships

The Program has strengthened its collaboration with educational institutes in the Central Asia region. ICARDA and the Gulistan State University of Uzbekistan signed a Memorandum of Understanding, which outlines areas where the two institutes will work together. The Program also set up new ICARDA Information Centers, and provided literature and equipment for existing centers, in Uzbekistan and Tajikistan.

To further develop the collaborative activities of the program, CACRP is enhancing its partnerships with existing and new donors and partners such as the Asian Development Bank, FAO, the Global Forum on Agricultural Research, the World Bank, the International Fund for Agricultural Development, and the Swedish International Development Cooperation Agency.

Planning action and building capacity

The Program organized several regional planning and coordination meetings in 2007. More than 300 NARS partners participated in these events. In addition, more than 120 scientists, extension staff, farmers and government representatives from all eight countries in the region participated in CACRP training programs. These programs covered subjects including plant genetic resources, production and use of salt-tolerant crops, seed quality, statistical analysis, and GIS. An English language course was also held for 20 young NARS researchers from the region.

Looking ahead

To further widen the scope of its activities, CACRP has prepared proposals for new projects on conservation agriculture, crop diversification, livestock and rangeland management, mountain agriculture, enhancing the productivity of salt-prone land and water resources, and socioeconomic and policy research.

NARS partners and ICARDA staff with the Center-Commissioned External Review team

Highland Regional Network

ICARDA's *Highland Regional Network* contributes to improving rural welfare in the highlands of CWANA through sustainable improvements in agricultural productivity.

The high drylands of Afghanistan, Iran, and Pakistan are agroecologically diverse, and support a wide range of crop, animal and forestry systems. Although moisture availability in some parts (from snowmelt), may be better than in the lowlands, cold and frost limit crop production. ICARDA focuses on breeding field crops for cold tolerance, on diversification of farming systems, and on the pastoral and crop–livestock systems which have a comparative advantage in these highlands.

Afghanistan

Working with communities

In 2007, ICARDA, Afghan researchers, and scientists from CIMMYT, IRRI, the World Vegetable Center and CIP, continued to work closely with farmers with the aim of moving Afghanistan towards self-sufficiency in staple crops. Farmers participated in 315 demonstrations of high-yielding varieties of wheat, rice, mung bean and potato.

ICARDA also continued to support village-based seed enterprises (VBSEs) as a way of producing much-needed quality seed. The potential benefits of new varieties cannot be realized without effective seed delivery systems. Twelve VBSEs received seed-processing equipment and 17 were given technical and business training.

Mint cultivation and mint-based products can be a viable alternative to growing opium poppies. Four new mint associations set up in 2007, two exclusively involving women, brought the total number of associations transforming mint from a garden herb to a commercial crop to eight.

Building partnerships

The ICARDA-Afghanistan team worked closely with the Afghan Ministry of Agriculture, Irrigation and Livestock to develop research projects on staple crops, animal husbandry, and irrigation.

Planning action and building capacity

ICARDA and the Afghan Ministry of Agriculture, Irrigation and Livestock also prepared an implementation strategy for Afghanistan's master plan for agriculture. Two national workshops for Afghan researchers covered technical, institutional and policy options, and designing and planning experiments.

Other training events included a workshop on goat husbandry, a train-the-trainers course on crop demonstrations, a course on seed technology and production for community seed enterprises, and a training course for women on producing mint water.

Looking ahead

Building on the success of community enterprises to produce seed potatoes, ICARDA and CIP have developed a new project, funded by USAID's Alternative Livelihoods Program North, to organize farmers in Badakhshan into seed producer groups. ICARDA will also strengthen collaboration with the World Vegetable Center and the CGIAR centers CIP, IRRI, and CIMMYT; new projects will also be developed with the World Agroforestry Centre.

Iran

Working with communities

During 2007, ICARDA launched participatory breeding activities with the communities of Gamsar and Kermanshah in collaboration with CENESTA (a national NGO) and the Dryland Agricultural Research Institute. We also launched a participatory technology development project in the Karkheh river basin for improving water productivity and enhancing livelihood resilience of farmers through better watershed management.

ICARDA and Iranian researchers jointly carried out more than 370 field experiments in crop breeding, crop management, crop diversification, water use efficiency, integrated pest management and sustainable management of natural resources. More than 60 trials helped to identify and demonstrate the benefits of new cereal, legume and oilseed varieties adapted to mild-to-cold and cold winter drylands. Trials of vetch and grasspea for forage in farmers' fields demonstrated the benefits of winter planting in areas with cold winters.

In other research, ICARDA and the Dryland Agricultural Research Institute performed more than 1,800 crosses and made preliminary selections of vetch, durum wheat and rapeseed.

ICARDA and Iranian researchers jointly carried out more than 370 field experiments in 2007

Building partnerships

ICARDA and the Agricultural Research and Education Organization (AREO) signed a joint five-year work plan for 2007–2011. The updated agreement will extend the collaboration with 10 AREO institutes and with the extension, horticulture, and agricultural production departments of the Ministry of Jihad-e-Agriculture, the University of Tehran, and the national NGO, CENESTA.

The new Karkheh River Basin projects enlarge the scope of partnerships with Iranian institutes and extend the regional and international aspects of joint Iran–ICARDA research.

Planning action and building capacity

ICARDA has two full-time staff in Iran, a coordinator and a water expert. In addition, ICARDA scientists spent 785 days supporting joint activities with different institutions. The Seed and Plant Certification and Registration Institute has built up capacity for virus testing using ELISA.

Other capacity building activities included three regional training courses with Wageningen International on genetic resources conservation, seed production, and related policies, attended by 34 Iranians and 14 other participants from 12 countries; and one in-country course on wheat improvement attended by 23 young researchers. In addition, eight Iranians participated in six courses held at ICARDA headquarters. Another 33 Iranian researchers attended international and regional conferences and workshops.

Looking ahead

Selection of cold-resistant germplasm and development of appropriate agricultural packages (improved water productivity, conservation agriculture, IPM of major pests and diseases) will be emphasized. New spring wheat lines that outyield the best checks will be selected under irrigated conditions in the lowlands. The germplasm and packages developed will be tested in other areas of the CWANA region.

ICARDA Director General Dr Mahmoud Solh and H.E. Dr Jafar Khalghani, Deputy Minister for Agricultural Research and President of AREO signing the five year workplan (2007-2012), accompanied by Dr Mohammad Jahansouz (Deputy Minister for Crop Production), Dr Mohamed Roozitalab and Dr Ziaoddin Shoai (International Relations Department of AREO) and Dr Ahmed Amri (Iran–ICARDA Coordinator).

Pakistan
Working with communities

In Pakistan, the Highland Regional Network focuses on improving feed resources, improving livestock productivity and adding value to livestock products.

In 10 villages in Punjab Province and five villages in Balochistan Province, around 180 members of women's organizations received training in better goat rearing. Female facilitators trained by the project worked with women's groups to encourage them to build on their local and traditional knowledge, to adopt new techniques, and to add value to goat products.

In severely degraded Barani areas, home to more than two million poor people, ICARDA and Pakistani partners are introducing low-cost methods of conserving water and soil, and providing better wheat varieties.

Building partnerships

ICARDA's partners in adaptive research projects in Pakistan include the Arid Zone Research Center, Agricultural Research Institute, Technology Transfer Institute, Balochistan Provincial Agricultural Research Institute and Livestock Department, the Center for Advanced Studies in Vaccinology and Biotechnology, the National Agricultural Research Center Islamabad, the Fodder Research Institute Sargodha, and the University of Agriculture, Faisalabad.

Collaborative projects cover research on arid zone agriculture in Balochistan funded by USAID, research on feed–livestock production and women's livelihoods funded by IFAD, and a research project on integrated watershed management funded by Austria. Other research in 2007 included studies on lentil varieties, protected horticultural crops, production of wheat, barley and lentil seed, introduction of drought-tolerant almond, pistachio, pomegranates and grapes, and water conservation.

The Government of Pakistan also finances two projects to develop better wheat varieties.

Planning action and building capacity

MSc and PhD students registered at Pakistani universities carry out project research. In addition, 13 scientists from Balochistan visited ICARDA to attend training courses.

Looking ahead

ICARDA and its partners will work towards more extensive, long-term projects that will contribute to developing the collaborative activities of the Network further.

Nile Valley and Sub-Saharan Africa Regional Program

The *Nile Valley and Sub-Saharan Africa Regional Program* contributes to increasing the incomes of smallholder farmers by improving the productivity and sustainability of production systems, while conserving natural resources and enhancing the research capacity of national scientists.

The Nile Valley and Sub-Saharan Africa Regional Program (NVSSARP) operates through established partnerships with Egypt, Eritrea, Ethiopia, Sudan, and Yemen, and is expanding its cooperation with other countries in sub-Saharan Africa.

Working with communities

NVSSARP researchers are working with communities to improve the incomes of smallholder farmers in the Nile Valley. In Egypt, farmers have participated in breeding improved barley; other research in the country focused on improving different cereals and food legumes. In Egypt and Sudan, whole communities have taken part in the management of scarce water resources in agriculture. Other research in Sudan focused on assessing and mapping poverty in the country.

In Eritrea, research has concentrated on improving the water productivity of cereals and food legumes, while in Ethiopia, sustainable production of cool-season food and forage legumes has played centre-stage. In addition, through a regional program in Egypt, Ethiopia, Sudan and Yemen, researchers have monitored stem rust race Ug99 in wheat, and are working to breed resistance against the disease.

Building partnerships

The Agricultural Research Corporation of Sudan is hosting NVSSARP at a new country office in Khartoum. And, a delegation from the Kenya Agricultural Research Institute visited ICARDA's headquarters to discuss cooperation in dryland research with a focus on crop–livestock integration, natural resource management, socioeconomic studies and capacity building.

ICARDA participated in the Forum for Agricultural Research in Africa Science Week and General Assembly held in Johannesburg, South Africa. At a side event focusing on ICARDA's experience in participatory and community research, partners in the non-tropical dry areas of sub-Saharan Africa discussed potential areas of collaboration.

Planning action and building capacity

NVSSARP held two national two-day planning meetings: one with Egypt's Agricultural Research Center in Cairo, and another with the Ethiopian Institute of Agricultural Research in Addis Ababa.

In addition to its regular planning meetings, NVSSARP organized 'traveling workshops' for national scientists and farmers to observe faba bean and wheat breeding activities in Egypt, and legume breeding activities in Ethiopia.

Other capacity-building events included a two-day intensive training course on wheat diseases in Egypt. Around 30 young scientists from research stations across Egypt participated in the event. Training focused on major wheat diseases with special emphasis on the identification and control of rusts, and the emergence of the Ug99 race of stem rust.

Other scientists, from Egypt, Ethiopia and Sudan, received training in genetic engineering, crop disease and improvement, experimental design, information and communication technologies, and water management.

Looking ahead

ICARDA prepared two proposals for new projects in 2007: 'Community and participatory approaches for conserving agrobiodiversity of cereals and food legumes in the Central Highlands of Ethiopia', in collaboration with the Ministry of Agriculture in Ethiopia; and 'Improving the livelihoods of rural communities in the Nile Valley and Red Sea region: Sustainable crop, livestock, land and water management'.

Scientists and farmers observe wheat breeding in Egypt, during a traveling workshop organized by ICARDA's Nile Valley and Sub-Saharan Africa Regional Program

North Africa Regional Program

The *North Africa Regional Program* contributes to poverty alleviation, natural resources conservation, improved crop and livestock productivity, diversification of production systems and incomes, human resources capacity building, and networking in the region.

The North Africa Regional Program (NARP) coordinates activities in Algeria, Libya, Mauritania, Morocco and Tunisia.

Working with communities

In 2007, NARP implemented both regional and country-based collaborative projects in North Africa. The country projects took place in Mauritania, Morocco and Tunisia.

In Mauritania, NARP worked with smallholder farmers to improve the management of rangeland and livestock. This project, supported by the African Development Bank, focused on soil and water conservation techniques and resources for feeding animals. For the first time in Mauritania, conservation structures such as contour ridges, terraces, and dikes were put into fields. The project has been so successful that development agencies are looking to replicate its techniques in other parts of the country.

In Morocco, NARP worked with the Moroccan Institut National de la Recherche Agronomique (INRA) on a project studying the biological diversity and cultural and economic value of medicinal, herbal and aromatic plants in the country. The project, which is supported by the US Department of Agriculture (USDA), has focused on the collection and conservation of germplasm, methods of growing selected plants, and ways in which farmers can market the plants locally and internationally.

In Tunisia, three projects, also funded by USDA, focused on small ruminant livestock, the use of GIS to manage watersheds, and biological control of weeds.

Building partnerships

NARP worked with the Tunisian government to organize the conference, International Solidarity in Protecting Africa and the Mediterranean Region from Climate Change Impacts, held in Tunis. ICARDA specialists delivered keynote papers and presentations and distributed publications. The ICARDA Director General took the opportunity to strengthen ties with Tunisia, by meeting with the Ministry of Agriculture's State Secretary and the President of the National Agricultural Research Institute of Tunisia. Dr Solh also visited the new national gene bank to discuss with its Director avenues for future collaboration.

ICARDA signed Memorandums of Understanding with the Agricultural Research Center of Libya, and INRA in Morocco. These agreements highlighted ongoing and new commitments to collaborative research. NARP teams also met with the Morocco division of USDA, to discuss on-going projects and future prospects.

On a regional level, NARP teams met with the Board of Directors of the Arab Fund for Economic and Social Development and the International Fund for Agricultural Development (IFAD). These meetings focused on the work of an ICARDA project developing sustainable livelihoods for agropastoral communities in West Asia and North Africa.

Planning action and building capacity

In 2007, NARP held a series of workshops, coordination meetings and training courses across North Africa. These meetings covered research areas that included involving local communities in strategies to combat desertification, adapting to climate change, conserving and improving barley and wheat, and implementing new greenhouse systems.

Looking ahead

NARP has developed project proposals for better water management and harvesting, cereal production and small ruminant productivity in Libya and Algeria. Other project proposals in Libya cover conservation agriculture, socio-economic research, and capacity building. In Mauritania, within a development project supported by the World Bank, NARP has submitted a proposal for research on managing watersheds and natural resources.

Mauritanian communities built contour ridges, terraces, and dikes to conserve soil and water, as part of a project run by the North Africa Regional Program. This project was so successful that development agencies are looking to replicate its techniques in other parts of the country.

West Asia Regional Program

The *West Asia Regional Program* promotes regional cooperation in research, capacity building and information dissemination, as well as providing germplasm nurseries, technical support, and training.

The West Asia Regional Program (WARP) covers Cyprus, Iraq, Jordan, Lebanon, Palestine, Syria and the lowlands of Turkey. In 2007, WARP provided improved crop varieties, technical support and training right across the region, including in the troubled countries of Iraq, Lebanon and Palestine.

Working with communities

The Program worked closely with smallholder farmers and communities on research projects in Jordan, Iraq, Lebanon and Syria. In Jordan, a project to optimize management of scarce water resources focused on harvesting water in the badia (steppe) benchmark site. The participatory breeding project for barley was extended to include wheat, chickpea and lentil and included several workshops, one of which attracted around 220 farmers and technicians from both Syria and Jordan.

In Iraq, farmers and researchers ran crop trials using seed supplied by WARP, which were designed to improve the production of wheat, barley and pulse and forage legumes. The trials helped to identify the best adapted varieties, and demonstrated the benefits of diversifying crops and using techniques such as minimum tillage. ICARDA and the Australian Centre for International Agricultural Research are supporting the trials with back-up research.

Developing the sustainable livelihoods of agropastoral communities is the focus of a sub-regional program in Jordan, Iraq, Lebanon and Syria. This program included a workshop on gender research for project participants.

Building partnerships

ICARDA and Jordan's Higher Council for Science and Technology (HCST) signed a Memorandum of Understanding. The agreement outlines areas of mutual interest in which the two institutions will strengthen their cooperation.

The Program also participated in a Regional Forum on Promoting National Alliances against Hunger in the Near East, organized under the Patronage of HRH Princess Basma Bent Talal of Jordan, and attended by representatives of eight countries from the region, NGOs, and civil society and research and development organizations. Following the meeting, ICARDA and the National Alliance in Jordan are now preparing a partnership agreement.

Planning action and building capacity

The 10th Iraq–ICARDA Biennial Coordination Meeting was attended by a delegation led by the Deputy Minister of Agriculture. The Second Palestine–ICARDA Biennial Coordination Meeting was attended by representatives from the Ministry of Agriculture and UNDP/PAPP (UNDP Programme of Assistance to the Palestinian People). In both meetings, delegates discussed ways to rehabilitate agriculture and developed joint proposals.

The recent conflicts in Lebanon severely affected the country's agriculture. During the 9th Lebanon–ICARDA Biennial Coordination Meeting, the Lebanese Minister of Agriculture and the Director General of ICARDA stressed the need to develop collaborative projects to rehabilitate agriculture, ensure efficient use of water resources, and halt land degradation.

Looking ahead

WARP has developed proposals for several new projects across the region. These include one on rainfed agriculture and livestock development in Yemen (to be funded by the Word Bank), and one on adaptation to climate change using local agrobiodiversity in the highlands of Yemen (funding is being sought from the Global Environment Facility). Three proposals have been developed in partnership with the Lebanese Agricultural Research Institute, and another two proposals are concerned with improving farmer livelihoods in Iraq and Palestine.

Project workers gather to learn about gender research in November 2007

Capacity Development

A well-trained cadre of scientists is critical for quality research and this year, as in previous years, ICARDA devoted a great deal of effort to enhancing the research capacity of national partners through knowledge transfer and dissemination. In 2007, 801 national researchers from 50 countries in Asia, Africa and Europe, and from other CGIAR centers, as well as 71 graduate researchers studying for MScs and PhDs, took part in both formal and informal training to complement ongoing research. One-fifth of these were women.

ICARDA's Capacity Development Unit (CDU) facilitated and coordinated 37 training courses, 21 at ICARDA and 16 in partner countries. Just over half the participants were trained outside ICARDA headquarters.

ICARDA's partners in capacity development included not only national agricultural research systems, but also regional and international agricultural research and training institutes, and international collaborative programs. These included CIMMYT, ILRI, IWMI, ICBA, FAO, IAEA, ICWIP, the Borlaug Global Rust Initiative, ACIAR, CLIMA, JICA, USAID, Purdue University, Wageningen International, NUFFIC; Hawaii University (KAHEAD–North Iraq), Iranian organizations (AREO, SPII, DARI, SPCRI, ECO), AIISWIP, IRESA-Tunisia, AZRC-Pakistan, NARC-Libya, INRA-Algeria, MAF-Oman, SMAAR and GCSAR-Syria, NARI-Eritrea, EIAR and ESE-Ethiopia, NARC-Nepal and the CGIAR Challenge Program on Water and Food.

The topics covered were integral to research themes, and often cut across several themes (see Box). Many of the courses included modules to boost institutional capacity in seed technology, policy issues, impact assessment, and setting research priorities.

Ties with universities reinforce the development, and ensure the quality, of research capacity building for NARS in dry areas. During the year, ICARDA strengthened links with Columbia University, USA; CASRII, Uzbekistan; Leipzig University, Bonn University, and the Technical University Berlin, Germany; Georgia Academy of Agricultural Science, Georgia; Southern Cross University, Australia; Cordoba University, Spain; University of Birmingham, UK; Wageningen University, The Netherlands; ANAS, Azerbaijan; ETH Zurich University, Switzerland; BOKU University, Austria; Asmara University, Eritrea; and Aleppo, Damascus, Tishreen, and Ba'ath Universities in Syria.

Selected topics covered by ICARDA training courses, 2007

- Participatory plant breeding and seed supply
- Seed health testing; seed certification and health
- Molecular characterization of small ruminant breeds
- Integrated crop and livestock production
- Integrated management of cereal and legume diseases, insect pests and viruses
- Cereal crop improvement
- Genotype x Environment analysis of data from multi-environment trials
- Gene bank management and germplasm conservation
- Variety management and quality assurance
- Seed marketing and promotion
- Quality assurance and management in farmer based seed operations
- Water management for improved water use efficiency – water harvesting and water management, modeling water productivity
- Salinity amelioration
- Design and analysis of experiments
- Genetic transformation of plants and detection of genetically modified organisms (GMOs)
- In vitro culture
- ICT in library and information management systems
- Experimental station management

Participants from Central and West Asia and North Africa, at a training course on integrated crop-livestock management, conducted at ICARDA headquarters

Appendix 1: Journal Articles

Abang, M.M., Bayaa, B., Abu-Irmaileh, B.E. and Yahyaoui, A. 2007. A participatory farming system approach for sustainable broomrape (*Orobanche* spp.) management in the Near East and North Africa. Crop Protection 26(12): 1723-1732.

Akhtar, A., Oweis, T., Rashid, M., El-Naggar, S. and Abdul Aal, A. 2007. Water harvesting options in the drylands at different spatial scales. Land Use & Water Resources Research (7): 1-13.

Akhtar, A. and Attila, Y. 2007. Effect of micro-catchment water harvesting on soil-water storage and shrub establishment in the arid environment. International Journal of Agriculture and Biology 9(2): 302-306.

Al-Jallad, R., Kumari, S.G. and Ismil, I.D. 2007. Integrated management of aphid-transmitted faba bean viruses in the coastal area of Syria. Arab Journal of Plant Protection 25(2): 175-180.

Alary, V., Nefzaoui, A. and Ben Jemaa, M. 2007. Promoting the adoption of natural resource management technology in arid and semi-arid areas: Modelling the impact of spineless cactus in alley cropping in Central Tunisia. Agricultural Systems 94 (2): 573-585.

Alary, V. and El Mourid, M. 2007. Changement reel et changement induit decalage ou perpetuelle recherche pour les zones arides d'Afrique du Nord [Between real change and induced changes - discrepancy or perpetual research for the arid areas of North Africa]. Cahiers Agricultures 16(4): 330-337.

Ansi, A., Kumari, S.G., Haj Kasem, A., Makkouk, K.M. and Muharram, I. 2007. The occurrence of barley yellow dwarf viruses on cereal crops and wild grasses in Syria. Arab Journal of Plant Protection 25(1): 1-9.

Ansi, A., Kumari, S.G., Haj Kasem, A., Makkouk, K.M. and Muharram, I. 2007. Effect of barley yellow dwarf virus-PAV on yield and grain quality of Yemeni wheat varieties. Arab Journal of Plant Protection 25(2): 163-170.

Anthofer, J. and Kroschel, J. 2007. Effect of *Mucuna* fallow on weed dry matter and composition in succeeding maize. Biological Agriculture & Horticulture 24(4): 397-414.

Aydogan, A., Sarker, A., Aydin, N., Kusmenoglu, I., Karagoz, A. and Erskine, W. 2007. Registration of 'Kafkas' lentil. Journal of Plant Registrations 1(1): 44-45.

Baber, M.A., van Ginkel, M., Klatt, A.R., Prasad, B. and Reynolds, M.P. 2007. Heritability, correlated response, and indirect selection involving spectral reflectance indices and grain yield in wheat. Australian Journal of Agricultural Research 58(5): 432-442.

Bader, S.M., Baum, M., Khierallah, H. and Choumane, W. 2007. The use of RAPDs technique for the detection of genetic stability of date palm plantlets derived from in vitro culture of inflorescence. Journal of Education and Science 20(3): 149-159.

Benli, B., Pala, M., Stockle, C. and Oweis, T. 2007. Assessment of winter wheat production under early sowing with supplemental irrigation in a cold highland environment using CropSyst simulation model. Agricultural Water Management 93(1): 45-53.

Bouajila, A., Abang, M.M., Haouas, S., Udupa, S.M., Rezgui, S., Baum, M. and Yahyaoui, A. 2007. Genetic diversity of *Rhynchosporium secalis* in Tunisia as revealed by pathotype, AFLP, and microsatellite analyses. Mycopathologia 163(5): 281-294.

Brennan, J.P., Condon, A.G., van Ginkel, M. and Reynolds, M.P. 2007. An economic assessment of the use of physiological selection for stomatal aperture-related traits in the CIMMYT wheat breeding programme. Journal of Agricultural Science, Cambridge 145(3): 187-194.

Buerli, M., Aw-Hassan, A. and Poulton, C. 2007. Microfinance respecting Islamic banking principles in marginal dry areas. Enterprise Development & Microfinance 18(2/3):189-202.

Casadesus, J., Kaya, Y., Bort, J., Nachit, M., Araus, J.L., Amor, S., Ferrazzano, G., Maalouf, F., Maccaferri, M., Martos, V., Ouabbou, H. and Villegas, D. 2007. Using vegetation indices derived from conventional digital cameras as selection criteria for wheat breeding in water-limited environments. Annals of Applied Biology 150(2): 227-236.

Ceccarelli, S. and Grando, S. 2007. Decentralized-participatory plant breeding: an example of demand driven research. Euphytica 155(3): 349-360.

Ceccarelli, S., Grando, S. and Baum, M. 2007. Participatory plant breeding in water-limited environments. Experimental Agriculture 43(4): 411-435.

Chabane, K., Abdalla, O., Sayed, H. and Valkoun, J. 2007. Assessment of EST-microsatellite markers for discrimination and genetic diversity in bread and durum wheat landraces from Afghanistan. Genetic Resources and Crop Evolution 54(5): 1703-1080.

Conrad, C., Dech, S.W., Hafeez, M.M., Lamers, J.P.A., Martius, C., and Strunz, G. 2007. Mapping and assessing of water use in a Central Asian irrigation system by utilizing MODIS remote sensing products. Irrigation & Drainage Systems 21(3/4): 197-218.

Dreccer, F., Borgognone, G.M., Ogbonnaya, F.C., Trethowan, R.M. and Winter, B. 2007. CIMMYT-selected derived synthetic bread wheats for rainfed environments: yield evaluation in Mexico and Australia. Field Crops Research 100: 218-228.

Dutilly-Diane, C. 2007. Pastoral economics and marketing in North Africa: a literature review. Nomadic Peoples 11(1): 69-90.

Dutilly-Diane, C., Acherkouk, M., Bechchari, A., Bouayad, A., El Koudrim, M. and Maatougui, A. 2007. Dominance communautaire dans l'exploitation des espaces pastoraux: impacts sur les modes de vie et implications pour la gestion des parcours du Maroc oriental [Community dominance in the use of pastoral territories: Impacts on livelihoods and implications for rangeland management in the Oriental region of Morocco]. Cahiers Agricultures 16(4): 338-346.

Edgington, S., Moore, D., El Bouhssini, M. and Sayyadi, Z. 2007. *Beauveria bassiana* for the control of Sunn Pest (*Eurygaster integriceps*) (Hemiptera: Scutelleridae) and aspects of the insect's daily activity relevant to a mycoinsecticide. Biocontrol Science & Technology 17(1/2): 63-79.

Emebiri, L.C., Moody, D.B., Black, C., van Ginkel, M. and Hernandez, E. 2007. Improvements in malting barley grain yield by manipulation of genes influencing grain protein content. Euphytica 156(1/2): 185-194.

Farahani, H. and Flynn, R.L. 2007. Map quality and zone delineation as affected by width of parallel swaths of mobile agricultural sensors. Biosystems Engineering 96(2): 151-159.

Farahani, H., Howell, T.A., Shuttleworth, W.J. and Bausch, W.C. 2007. Evapotranspiration: Progress in measurement and modeling in agriculture. Transactions of the ASABE 50(5): 1627-1638.

Ferrio, J.P., Mateo, M.A., Bort, J., Abdalla, O., Voltas, J. and Araus, J.L. 2007. Relationships of grain d13C and d18O with wheat phenology and yield under water-limited conditions. Annals of Applied Biology 150(2): 207-215.

Fikre, A., Sarker, A., Ahmed, S., Ali, K. and Erskine, W. 2007. Registration of 'Teshale' lentil. Journal of Plant Registrations 1(1): 45.

Fikru, E., Sarker, A., Fikre, A., Ahmed, S., Ali, K. and Erskine, W. 2007. Registration of 'Assano' lentil. Journal of Plant Registrations 1(1): 41.

Fufa, F., Baum, M., Grando, S., Kafawin, O. and Ceccarelli, S. 2007. Consequences of a decentralized participatory barley breeding programme on changes in SSR allele frequency and diversity in one cycle of selection. Plant Breeding 126(5): 527-532.

Gahoonia, T.S., Ali, R., Malhotra, R.S., Jahoor, A. and Matiur Rahman, M. 2007. Variation in root morphological and physiological traits and nutrient uptake of chickpea genotypes. Journal of Plant Nutrition 30(6): 829-841.

Guo, P., Bai, G., Carver, B., Li, R., Bernardo, A. and Baum, M. 2007. Transcriptional analysis between two wheat near-isogenic lines contrasting in aluminum tolerance under aluminum stress. Molecular Genetics & Genomics 227(1): 1-12.

Guo, P., Baum, M., Varshney, R.K., Graner, A., Grando, S. and Ceccarelli, S. 2007. QTLs for chlorophyll and chlorophyll fluorescence parameters in barley under post-flowering drought. Euphytica DOI: 10.1007/s10681-007-9629-6.

Gupta, R. and Seth, A. 2007. A review of resource conserving technologies for sustainable management of the rice–wheat cropping systems of the Indo-Gangetic plains. Crop Protection 26(3): 436-447.

Gupta, R. and Seth, A. 2007. Conservation agriculture in South Asia. Journal of Agricultural Science, Cambridge 145(3): 207-214.

Homann, S., Rischkowsky, B. and Steinbach, J. 2007. The effect of development interventions on the use of indigenous range management strategies in the Borana Lowlands in Ethiopia. Land Degradation and Development DOI: 10.1002/ldr.845.

Ibrahim, J., El Bouhssini, M., Abdulhai, M. and Trissi, A.N. 2007. The effect of egg parasitoids in regulating Sunn Pest (*Eurygaster integriceps* Puton) populations. Research Journal of Aleppo University, Agricultural Sciences Series 52: 13-22.

Ibrakhimov, M., Khamzina, A., Forkutsa, I., Paluasheva, G., Lamers, J.P.L., Tischbein, B., Vlek, P.L.G. and Martius, C. 2007. Groundwater table and salinity: Spatial and temporal distribution and influence on soil salinization in Khorezm region (Uzbekistan, Aral Sea Basin). Irrigation & Drainage Systems 21(3/4): 219-236.

Inagaki, M.N., Valkoun, J. and Nachit, M.M. 2007. Effect of soil water deficit on grain yield in synthetic bread wheat derivatives. Cereal Research Communications 35(4): 1603-1608.

Kapur, S., Ryan, J., Akca, E., Celik, I., Pagliai, M. and Tulun, Y. 2007. Influence of Mediterranean cereal-based rotations on soil micromorphological characteristics. Geoderma 142(3/4): 318-324.

Kharrat, M., Sarker, A. and Erskine, W. 2007. Registration of 'Saliana' lentil. Journal of Plant Registrations 1(1): 42.

Kharrat, M., Sarker, A. and Erskine, W. 2007. Registration of 'Kef' lentil. Journal of Plant Registrations 1(1): 43.

Khatib, F., Koudsieh, S., Ghazal, B., Barton, J.E., Tsujimoto, H. and Baum, M. 2007. Developing herbicide resistant lentil (*Lens culinaris medikus* subsp. *culinaris*) through agrobacterium mediated transformation. Arab Journal of Plant Protection 25(2): 185-192.

Kirigwi, F.M., van Ginkel, M., Brown-Guedira, G., Gill, B.S., Paulsen, G.M. and Fritz, A.K. 2007. Markers associated with a QTL for grain yield in wheat under drought. Molecular Breeding 20(4): 401-413.

Kubo, K., Elouafi, I., Watanabe, N., Nachit, M.M., Inagaki, M.N., Iwama, K. and Jitsuyama, Y. 2007. Quantitative trait loci for soil-penetrating ability of roots in durum wheat. Plant Breeding 126(4): 375-378.

Kumari, S.G. and Makkouk, K.M. 2007. Virus diseases of faba bean (*Vicia faba* L.) in Asia and Africa. Plant Viruses 1(1): 93-105.

Kumari, S.G., Ismil, I.D. and Al-Jallad, R. 2007. The effect of the seed treatment of faba beans with Thiamethoxam and Imidacloprid pesticides in reducing the incidence of bean leaf roll luteovirus. Tishreen University Journal for Studies and Scientific Research - Agriculture Science Series 29 (1): 171-180.

Ladha, J.K., Pathak, H. and Gupta, R. 2007. Sustainability of rice–wheat cropping systems: issues, constraints and remedial options. Journal of Crop Improvement 19(1/2): 125-136.

Larbi, A., Etela, I., Nwokocha, H.N., Oji, U.I., Anyanwu, N.J., Gbaraneh, L.D., Anioke, S.C., Balogun, R.O. and Muhammad, I.R. 2007. Fodder and tuber yields, and fodder quality of sweet potato cultivars at different maturity stages in the West African humid forest and savanna zones. Animal Feed Science and Technology 135(1-2): 126-138.

Machlab, H., Sarker, A., Kiwan, P., El-Hassan, H. and Erskine, W. 2007. Registration of 'Hala' lentil. Journal of Plant Registrations 1(1): 40.

Machlab, H., Sarker, A., Kiwan, P., El-Hassan, H. and Erskine, W. 2007. Registration of 'Rachayya' lentil. Journal of Plant Registrations 1(1): 46.

Malhotra, R.S., Singh, M. and Erskine, W. 2007. Genotype x environment interaction and identification of dual-season cultivars in chickpea. Euphytica 158(1/2): 119-127.

Malhotra, R.S., Bejiga, G., Anbessa, Y., Eshete, M., Tadesse, N., Daba, K., Fikre, A., Ahmed, S. and Khalaf, G. 2007. Registration of 'Teji', a Kabuli chickpea. Journal of Plant Registrations 1(2): 111.

Malhotra, R.S., Bejiga, G., Anbessa, Y, Eshete, M., Tadesse, N., Daba, K., Fikre, A., Ahmed, S. and Khalaf, G. 2007. Registration of 'Ejere', a Kabuli chickpea. Journal of Plant Registrations 1(2): 112.

Malhotra, R.S., El-Bouhssini, M. and Joubi, A. 2007. Registration of seven improved chickpea breeding lines resistant to leaf miner. Journal of Plant Registrations 1(2): 145-146.

Mariani, L., Jimenez, J.J., Asakawa, N., Thomas, R.J. and Decaens, T. 2007. What happens to earthworm casts in the soil? A field study of carbon and nitrogen dynamics in Neotropical savannahs. Soil Biology & Biochemistry 39(3): 757-767.

Moeller, C., Pala, M., Manschadi, A.M., Meinke, H. and Sauerborn, J. 2007. Assessing the sustainability of wheat-based cropping systems using APSIM: model parameterization and evaluation. Australian Journal of Agricultural Research 58: 75-86.

Ogbonnaya, F.C., Imtiaz, M. and De Pauw, E. 2007. Haplotype diversity at pre-harvest sprouting QTLs in wheat. Genome 50: 107-118.

Ogbonnaya, F.C., Trethowan, R., Dreccer, F., Lush, D., Shepperd, J. and van Ginkel, M. 2007. Yield of synthetic backcross-derived lines in rainfed environments of Australia. Euphytica 157(3): 321-336.

Orabi, J., Backes, G., Wolday, A., Yahyaoui, A. and Jahoor, A. 2007. The Horn of Africa as a centre of barley diversification and a potential domestication site. Theoretical & Applied Genetics 114(6): 1117-1127.

Pala, M., Ryan, J., Zhang, H., Singh, M. and Harris, H.C. 2007. Water-use efficiency of wheat-based rotation systems in a Mediterranean environment. Agricultural Water Management 93(3): 136-144.

Qadir, M., Sharma, B.R., Bruggeman, A., Choukr-Allah, R. and Karajeh, F. 2007. Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries. Agricultural Water Management 87(1): 2-22.

Qadir, M., Oster, J.D., Schubert, S., Noble, A.D. and Sahrawat, K.L. 2007. Phytoremediation of sodic and saline-sodic soils. Advances in Agronomy 96: 197-247.

Qadir, M., Schubert, S., Badia, D., Sharma, B.R., Qureshi, A.S. and Murtaza, G. 2007. Amelioration and nutrient management strategies for sodic and alkali soils. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition & Natural Resources 2 (021): 1-13.

Rajaram, S., Sayre, K.D., Diekmann, J., Gupta, R. and Erskine, W. 2007. Sustainability considerations in wheat improvement and production. Journal of Crop Improvement 19 (1/2): 105-123.

Ryan, J., El Mourid, M., Shroyer, J.P. and El Gharous, M. 2007. The dryland agriculture applied research project in Morocco: A perspective 12 years after completion. Journal of Natural Resources & Life Sciences Education 36: 120-128.

Sabaghpour, S.H., Sarker, A., Safikhani, M. and Erskine, W. 2007. Registration of 'Gachsaran' lentil. Journal of Plant Registrations 1(1): 39.

Sarker, A., Singh, M., El-Ashkar, F., Erskine, W. and De-Pauw, E. 2007. Approaches to rationalising selection of test environments for on-farm lentil variety trials in Mediterranean rainfed cropping systems. Australian Journal of Agricultural Research 58(4): 335-341.

Shi, Z., Ruecker, G.R., Muller, M., Conrad, C., Ibragimov, N., Lamers, J.P.A., Martius, C., Strunz, G., Dech, S.W. and Vlek, P.L.G. 2007. Modeling of cotton yields in the Amu Darya river floodplains of Uzbekistan integrating multitemporal remote sensing and minimum field data. Agronomy Journal 55(9): 1317-1326.

Shiying, B., Xiaoming, W., Zhendong, Z., Xuxiao, Z., Kumari, S.G., Freeman, A. and Van Leur, J.A.G. 2007. Survey of faba bean and field pea viruses in Yunnan Province, China. Australasian Plant Pathology 36 (4): 347-353.

Siddique, K.H.M., Regan, K.L. and Malhotra, R.S. 2007. Registration of 'Nafice' Kabuli chickpea. Crop Science 47(1): 436-437.

Siddique, K.H.M., Regan, K.L. and Malhotra, R.S. 2007. Registration of 'Almaz' Kabuli chickpea cultivar. Crop Science 47(1): 437.

Thomas, R.J., De Pauw, E., Qadir, M., Amri, A., Pala, M., Yahyaoui, A., El-Bouhssini, M., Baum, M., Iniguez, L. and Shideed, K. 2007. Increasing the resilience of dryland agro-ecosystems to climate change. Journal of Semi-Arid Tropical Agricultural Research 4(1): 1-37.

van Ginkel, M. and Ogbonnaya, F.C. 2007. Novel genetic diversity from synthetic wheats in breeding cultivars for changing production conditions. Field Crops Research 104(1/3): 86-94.

Vargas, S., Larbi, A. and Sanchez, M. 2007. Analysis of size and conformation of native Creole goat breeds and crossbreds used in smallholder agrosilvopastoral systems in Puebla, Mexico. Tropical Animal Health and Production 39(4): 279-286.

Weicheng, W. 2007. Coastline evolution monitoring and estimation: a case study in the region of Nouakchott, Mauritania. International Journal of Remote Sensing 28(24): 5461-5484.

Ye, G., Moody, D., Emebiri, L. and Van Ginkel, M. 2007. Designing an optimal marker-based pedigree selection strategy for parent building in barley in the presence of repulsion linkage, using computer simulation. Australian Journal of Agricultural Research 58(3): 243-251.

Zewde, T., Fininsa, C., Sakhuja, K.P. and Seid-Ahmed, K. 2007. Association of white rot (*Sclerotium cepivorum*) of garlic with environmental factors and cultural practices in the North Shewa highlands of Ethiopia. Crop Protection 26(10): 1566-1573.

Appendix 2: ICARDA's Donors and Investors in 2007

ICARDA receives two main types of funding: unrestricted or 'core' funding, and restricted funding and grants that are directed to specific initiatives or projects.

Unrestricted Funding

Australia
Belgium
Canada
China
Denmark
Egypt
France
Germany
India
Iran
Italy
Japan
Norway
South Africa
Spain
Sweden
Switzerland
Syria
The Netherlands
Turkey
United Kingdom
United States of America
World Bank (IBRD)

Restricted Funding/Grants

Asian Development Bank (ADB)
Arab Fund for Economic and Social Development (AFESD)
Australia
Austria
BASF, Germany
Canada
Center for Development Research (ZEF), University of Bonn
CGIAR
Denmark
Egypt
Ethiopia
European Commission
Food and Agriculture Organization of the United Nations (FAO)
FAO/UNEP
France
General Commission for Scientific Agricultural Research, Syria
Germany
Global Crop Diversity Trust
GM-UNCCD
Gulf Cooperation Council
India
INRA-INRAT
International Development Research Centre (IDRC)
International Fund for Agricultural Development (IFAD)
International Nutrition Foundation
Iran
Italy
Japan
Japan International Research Center for Agricultural Sciences (JIRCAS)
Korea
Kurdistan Regional Government (Iraq)
Libya
Louis Berger Group, Inc.
Mauritania
Morocco
Pakistan
Switzerland
Syria
The Netherlands
OPEC Fund for International Development (OFID)
Turkey
UNDP
UNEP
UNESCO
United Nations University
UK Department for International Development (DFID)
University of Minnesota
University of Saskatchewan
University of Wisconsin
USAID
USAID/Development Alternatives Inc.
USAID/RAMP/Chemonics
USAID/PADCO
USDA
Wageningen University
World Bank (IBRD)

Appendix 3: Collaboration with Advanced Research Institutes and Regional and International Organizations

CGIAR Centers and Regional/International Organizations

- ACSAD (Arab Center for Studies of Arid Zones and Dry Lands)
- AVRDC (World Vegetable Center - formerly Asian Vegetable Research and Development Center)
- Bioversity International (formerly IPGRI)
- Borlaug Institute at Texas A&M University
- CIAT (International Center for Tropical Agriculture)
- CIHEAM (International Centre for Advanced Mediterranean Agronomic Studies)
- CIMMYT (International Maize and Wheat Improvement Center)
- CIP (International Potato Center)
- FAO (Food and Agriculture Organization of the United Nations)
- ICBA (International Center for Biosaline Agriculture)
- ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)
- IFPRI (International Food Policy Research Institute)
- ILRI (International Livestock Research Institute)
- IRRI (International Rice Research Institute)
- IWMI (International Water Management Institute)
- Observatoire du Sahara et du Sahel and Oasis
- TerrAfrica partnership
- UNESCO-MAB (UN Educational, Scientific and Cultural Organization - Man and the Biosphere Programme)
- United Nations University

Australia: Department of Agriculture and Food, Western Australia

- Australian Winter Cereals Collection, Tamworth
- Centre for Legumes in Mediterranean Agriculture (CLIMA)
- Cooperative Research Centre for Molecular Plant Breeding
- Department of Agriculture, Western Australia
- Department of Primary Industries (DPI), Tamworth Centre for Crop Improvement
- Department of Primary Industries (DPI), Horsham, Victoria
- Department of Primary Industries (DPI), Knoxfield Centre, Victoria
- Grain Foods Cooperative Research Centre Ltd.
- Grains Research and Development Corporation
- Land and Food Sciences, University of Queensland
- Plant Breeding Institute, University of Sydney
- South Australia Department of Agriculture
- Southern Cross University
- University of Adelaide, Waite Institute
- University of Western Australia

Austria

- Landwirtschaftlich-chemische Bundesversuchsanstalt (BAVL)
- University of Natural Resources and Applied Life Sciences (BOKU), Vienna

Belgium

- University of Ghent
- University of Leuven

Brazil

- EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária/Brazilian Agricultural Research Corporation)

Canada

- Agriculture Canada, Field Crop Development Centre, Alberta
- Agriculture and Agri-Food Canada
- Canadian International Development Agency
- CGIAR-Canada Linkage Funds
- Crop Development Centre, University of Saskatchewan

Denmark
- Danish Institute of Agricultural Sciences
- Risø National Laboratory, Plant Biology and Biogeochemistry Department
- Royal Veterinary and Agricultural University, Department of Agricultural Sciences, Plant and Soil Science Laboratory

France
- Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)
- Centre National de la Recherche Scientifique (CNRS)
- Institut National de la Recherche Agronomique (INRA)
- Institut de Recherche pour le Développement (IRD)
- Université de Paris-Sud, Labo Morphogenèse Végétale Expérimentale

Germany
- BASF
- Biologische Bundesanstalt für Land- und Forstwirtschaft (BBA) (Federal Biological Research Centre for Agriculture and Forestry), Department of Plant Virology, Microbiology and Biosafety, Braunschweig
- Center for Development Research (ZEF), University of Bonn
- Federal Ministry for Economic Cooperation and Development (BMZ)
- IPK-Gatersleben
- University of Bonn
- University of Frankfurt am Main
- University of Hannover
- University of Hohenheim
- University of Kiel

Italy
- Consorzio Ricerca Filiera Lattiero-Casearia, Regione Siciliana (CoRFiLaC)
- Istituto Sperimentale per la Cerealicoltura, Sezione di Fiorenzuola d'Arda
- National Institute of Geophysics and Volcanology
- Udine University
- University of Bologna
- University of Tuscia, Viterbo
- Germplasm Institute, Bari
- ENEA (Italian Research Agency for New Technologies, Energy and the Environment)

Japan
- Japan International Research Center for Agricultural Sciences (JIRCAS)
- Tottori University
- Yokohama City University

Korea
- Rural Development Administration

Netherlands
- Wageningen University and Research Centre
- Wageningen University, Department of Plant Science, Laboratory of Plant Breeding

Russia
- N.I. Vavilov Research Institute for Plant Industry

Spain
- University of Barcelona
- University of the Basque Country
- University of Córdoba
- University of Lleida and Institut de Recerca i Tecnologia Agroalimentàries (UdL-IRTA)

Switzerland
- Station Fédérale de Recherches Agronomiques de Changins (RAC), Nyon
- Swiss Centre for International Agriculture (ZIL)
- Swiss Federal Institute of Technology (ETH)
- Swiss Federal Institute of Technology (ETH), Animal Nutrition Department
- Swiss Federal Institute of Technology (ETH), Institute of Plant Science/Phytopathology
- University of Bern

United Kingdom
- Birmingham University
- British Society of Animal Science
- CABI Bioscience
- Centre for Arid Zone Studies, University of Wales
- Macaulay Land Use Research Institute
- Macaulay Research Consultancy Services Ltd.
- National Institute of Agricultural Botany
- Natural Resources Institute
- Rothamsted Research
- Scottish Crop Research Institute

United States Of America
- Busch Agricultural Resources Inc.
- Cornell University
- Michigan State University/IPM Collaborative Research Support Program
- Oregon State University
- Purdue University
- Stephen F. Austin State University
- University of California, Davis
- University of Delaware
- University of Florida, Gainesville
- University of Hawaii
- University of St. Paul, Minnesota
- University of Vermont
- University of Wisconsin
- Virginia Polytechnic
- Washington State University
- Yale University

Appendix 4: Financial Summary

Statement of Activity (US$x000)

	2007	2006
REVENUES		
Grants (core and restricted)	27,557	24,318
Other revenues and gains	1,062	1,650
Total revenues and gains	**28,619**	**25,968**
EXPENSES AND LOSSES		
Program related expenses	23,171	24,570
Management and general expenses	4,825	3,238
Other losses and expenses	48	-
Total expenses and losses	28,044	27,808
Indirect cost recovery	(1,113)	(810)
Net expenses and losses	**26,931**	**26,998**
EXCESS REVENUES OVER EXPENSES	**1,688**	**(1,030)**

Statement of Financial Position (US$x000)

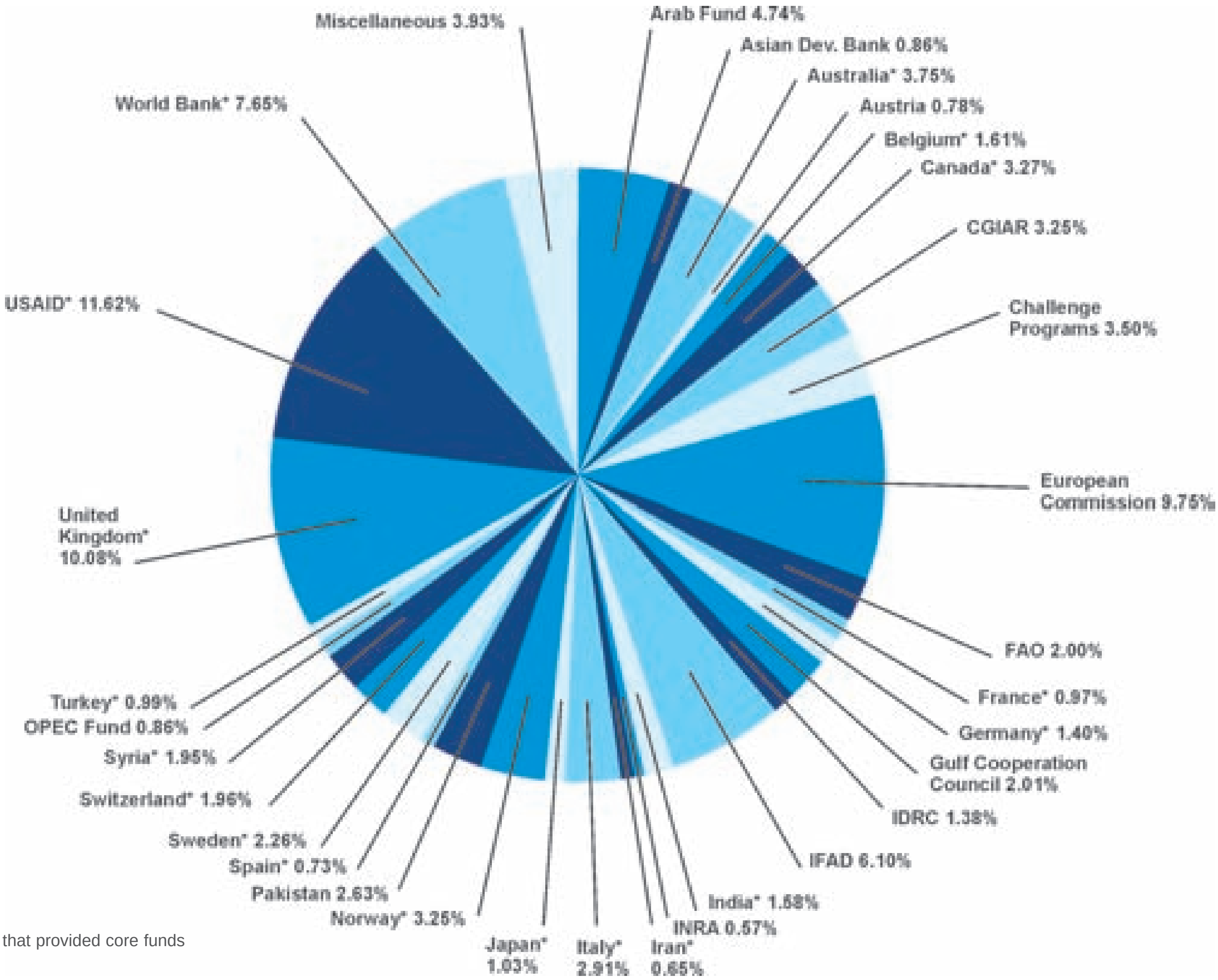
	2007	2006
ASSETS		
Current assets	29,904	26,603
Property and equipment	3,150	3,446
Other assets	5,223	4,645
Total assets	**38,277**	**34,694**
LIABILITIES AND ASSETS		
Current liabilities	15,931	14,605
Long term liabilities	8,757	8,188
Total liabilities	24,688	22,793
Net assets	13,589	11,901
Total liabilities and net assets	**38,277**	**34,694**

Statement of Grant Revenues, 2007 (US$x000)

Donors	Amount
Arab Fund	1,307
Asian Development Bank	238
Australia*	1,034
Austria	214
Belgium*	444
Canada*	900
CGIAR	896
Challenge Programs	964
Denmark*	55
Egypt*	91
Ethiopia	40
European Commission	2,687
FAO	551
France*	267
GCSAR - Syria	51
Germany*	385
Global Crop Diversity Trust	89
GM-UNCCD	119
Gulf Cooperation Council	554
IDRC	380
IFAD	1,680
India*	436
INRA-INRAT	156
Iran*	180
Italy*	803
Japan*	283
JIRCAS	19
Korea	22
Kurdistan Regional Government	75
Libya	56
Louis Berger Group Inc.	7
Morocco	94
Norway*	896
Pakistan	724
Spain	200
Sweden*	622
Switzerland*	540
Syria*	536
The Netherlands*	41
The OPEC Fund	236
Turkey*	274
UNEP	43
UNESCO	13
UNDP	27
United Kingdom*	2,779
University of Saskatchewan	5
UNU	11
USAID*	3,201
USDA	127
Wageningen University	5
World Bank*	2,108
Miscellaneous	92
TOTAL	**27,557**

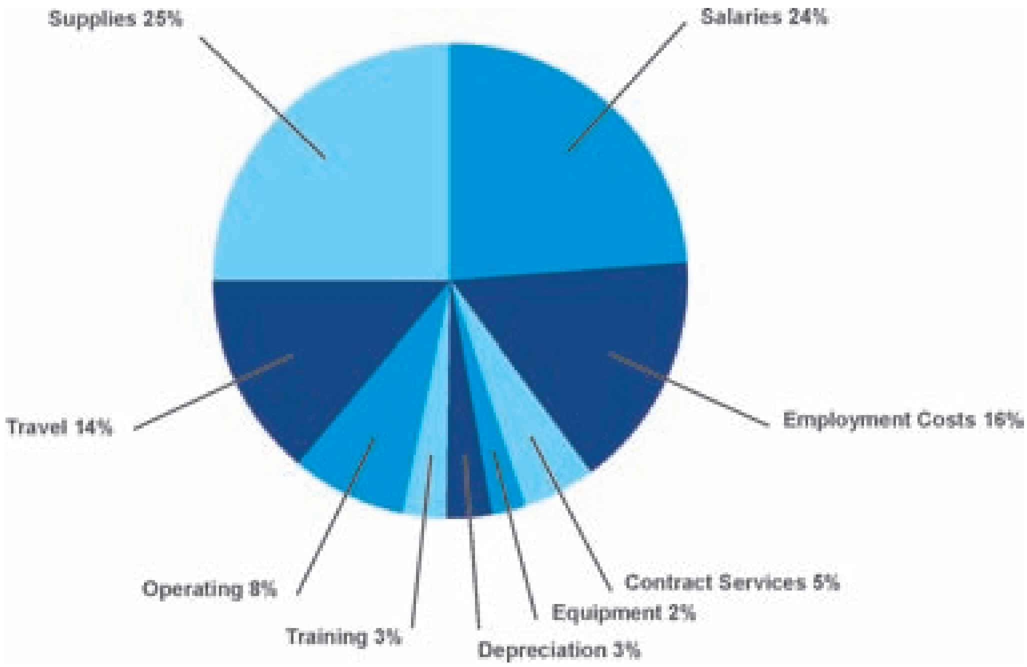
* Donors that provided core funds

Donor Contributions 2007

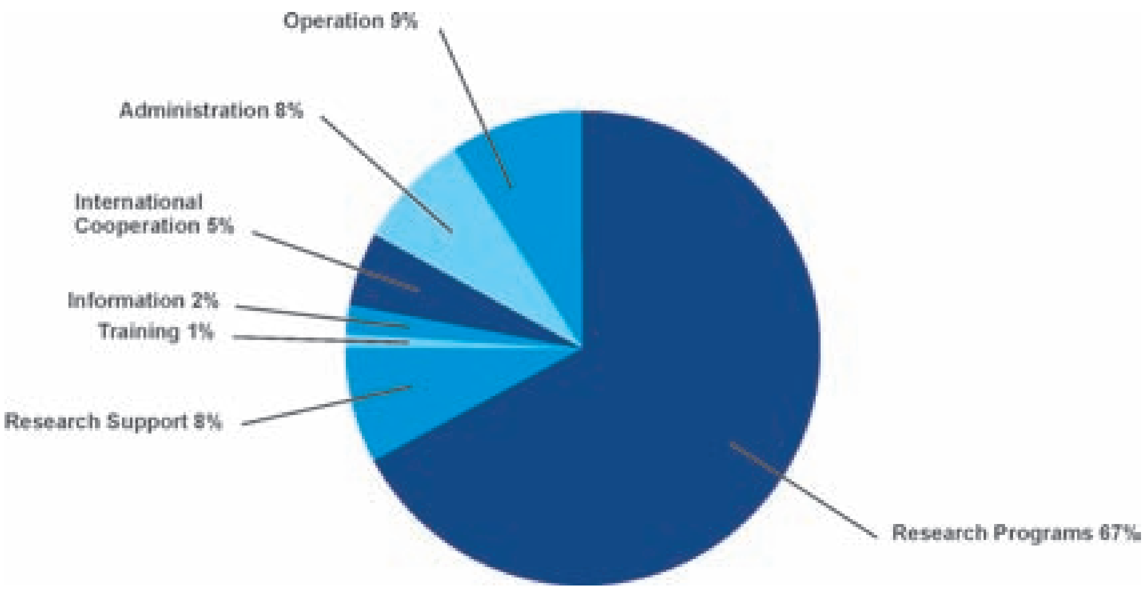


* Donors that provided core funds

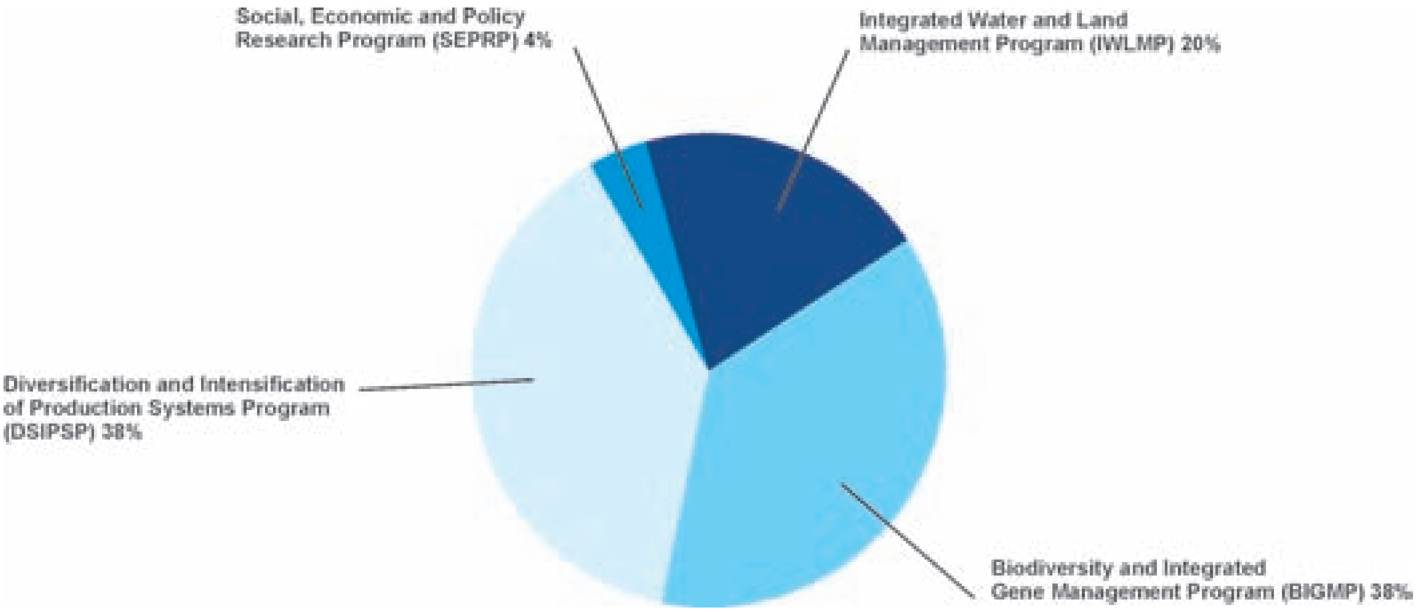
Expenditures by Expense Category



Expenditures by Program and Activities



Expenditures by Research Programs



Appendix 5: Board of Trustees

Appendix 6: Senior Staff (as of 31 December 2007)

** Staff who joined in 2007 ** Staff who departed in 2007*

Director General's Office
Dr Mahmoud Solh, Director General
Dr Scott Christiansen, Executive Assistant to the Director General*
Dr Ir Maarten van Ginkel, Deputy Director General – Research*
Dr Rajendra Singh Paroda, Assistant Director General – International Cooperation
Dr William Erskine, Assistant Director General – Research**
Mr Koen Geerts, Assistant Director General – Corporate Services*
Ms Houda Nourallah, Administrative Officer to the Director General and Board of Trustees

Resource Mobilization and Project Development Unit
Dr Elizabeth Bailey, Head
Ms Ilona Kononenko, Grants Management Officer

Corporate Services
Mr Koen Geerts, Assistant Director General*
Mr Michel Valat, Director of Corporate Services**
Mr Essam Abd Alla Saleh Abd El-Fattah, Assistant Director of Corporate Services**

Government Liaison
Dr Ahmed El-Ahmed, Assistant Director General

Finance Department
Mr Bruce Fraser, Finance Director*
Mrs Imelda Silang, Accounting Manager
Mr Mohamed Samman, Treasury Officer
Mrs Leny Medenilla, Budget Officer
Mr Awad Awad, MIS Team Leader
Dr Fadil Rida, MIS Applications Specialist
Mr Jong Won Lee, Director**
Mr Ahmed El-Shennawy, Associate Director of Finance**

Integrated Water and Land Management Program
Dr Theib Oweis, Director
Dr Akhtar Ali, Water and Soil Engineer
Dr Jurgen Thomas Anthofer, Researcher on Integrated Natural Resource Management in Dry Mountainous Areas
Dr Bogachan Benli, Post-Doctoral Fellow, Irrigation and Water Management**
Dr Adriana Bruggeman, Agricultural Hydrology Specialist
Dr Hamid Reza Jalali Farahani, Specialist in Irrigation and Water Management
Mr Venkataramani Govindan, Water Management Communications and Knowledge Sharing Specialist*
Dr Mohammed Karrou, Water and Drought Management Specialist*
Dr Manzoor Qadir, Marginal Water Management Specialist
Dr Richard Thomas, Senior Scientist for Desertification and Land Degradation
Dr Ashraf Tubeileh, Post-Doctoral Fellow, Nutrient and Water Flows in CWANA**
Dr Francis Turkelboom, Soil Conservation/Land Management Specialist

Biodiversity and Integrated Gene Management Program
Dr Sanjaya Rajaram, Program Director and Director of Joint ICARDA-CIMMYT Wheat Program
Dr Mathew Musumbale Abang, Post-Doctoral Fellow, Legume Pathologist
Mr Fadel Al-Afandi, Research Associate I**
Dr Akinnola Nathaniel Akintunde, International Crop Information System and International Nursery Scientist
Dr Michael Baum, Biotechnologist
Dr Flavio Capettini, Barley Breeder
Dr Jean Claude Chabane, Biotechnologist**
Dr Bitore Djumahanov, Cereal/Legume Breeder
Dr Fekadu Fufa Dinssa, Post-Doctoral Fellow, Barley Breeder**
Dr Mustapha El-Bouhssini, Entomologist
Dr Osman Abdalla El Nour, Bread Wheat Breeder
Dr Stefania Grando, Barley Breeder
Dr Muhammad Imtiaz, Chickpea Breeder*
Dr Masanori Inagaki, JIRCAS Scientific Representative
Dr Shaaban Khalil, Consultant**
Dr Safaa Kumari, Manager of the Virology Laboratory
Dr Fouad Maalouf, Faba Bean Breeder*
Dr Moussa Guirgis Mosaad, Visiting Scientist**
Dr Ali Abdel Moneim, Forage/Legume Breeder**
Dr Masahiko Mori, Research Fellow
Dr Miloudi Nachit, Durum Wheat Breeder
Dr Francis C. Ogbonnaya, Research Scientist, Bread Wheat Breeding/Biotechnology*
Dr Ashutosh Sarker, Lentil Breeder
Dr Maria von Korff Schmising, Post-Doctoral Fellow, Allelic Gene Expression in ICARDA Mandated Crops
Dr Sripada M. Udupa, Biotechnologist/Geneticist
Dr Amor Yahyaoui, Senior Cereal Pathologist

Seed Unit
Dr Zewdie Bishaw, Head – Seed Unit
Mr Abdul Aziz Niane, Research Associate

Genetic Resources Section (GRS)
Dr Ahmed Amri, Head
Dr Siham Asaad, Head of ICARDA Seed Health Laboratory
Dr Bonnie Jean Furman, Legume Germplasm Curator**
Mr Bilal Humeid, Research Associate I
Mr Jan Konopka, Germplasm Documentation Officer
Dr Kenneth Street, Legume Germplasm Curator

Diversification and Sustainable Intensification of Production Systems Program
Dr Ahmed Eltigani Sidahmed, Acting Director
Dr Hanadi Ibrahim El-Dessougi, Verification and Up-scaling Scientist**
Dr Catherine Farnworth, Coordinator, CWANA Sub-global Component of the IAASTD**
Ms Azusa Fukuki, Research Associate**
Dr Luis Iniguez, Senior Small Ruminant Scientist
Dr Zakir Khalikulov, Germplasm Scientist/Liaison Officer
Dr Asamoah Larbi, Pasture and Forage Production Specialist
Dr Najibullah Malik, RALF Manager
Dr Colin Piggin, Director – Diversification and Sustainable Improvement of Rural Livelihoods**
Dr Mustafa Pala, Wheat-Based Systems Agronomist**
Dr Barbara Ann Rischkowsky, Senior Livestock Scientist (Small Ruminants Management)
Dr Safouh Rihawi, Research Associate**
Dr Abdul Bari Salkini, Agricultural Economist, Liaison Scientist**
Mr Tsutomu Tamada, Associate Expert**
Ms Monika Zaklouta, Research Associate I

Training Coordination Unit
Mr Afif Dakermanji, Training Officer

Social, Economic and Policy Research Program (SEPRP)
Dr Kamel Shideed, Director
Dr Mohamed Abdelwahab Ahmed, Agricultural Policy Specialist*
Dr Aden Aw-Hassan, Agricultural Economist
Dr Koffi Nenonene Amegbeto, Agricultural Economist
Dr Malika Martini Abdelali, Socio-economist, Community and Gender Analysis Specialist
Dr Celine Dutilly-Diane, Visiting Scientist
Dr Ahmed Mazid, Agricultural Economist
Dr Farouk Shomo, Socio Economist Researcher

Geographic Information Systems Unit (GISU)
Dr Eddy De Pauw, Head
Dr Weicheng Wu, Remote Sensing Specialist*

Communication, Documentation and Information Services (CODIS)
Dr Surendra Varma, Head**
Dr Moyomola Bolarin, Multimedia Training/Material Specialist
Dr Nuhad Maliha, Library and Information Services Manager
Dr Andrea Pape-Christiansen, Visiting Scientist*
Mr Ravi Prasad, Communication/Media Specialist*
Mr Ajay Varadachary, Communication Specialist

Computer and Biometrics Services
Dr Zaid Abdul-Hadi, Head
Mr Hashem Abed, Scientific Databases Specialist
Mr Michael Sarkisian, Senior Systems Engineer
Dr Murari Singh, Senior Biometrician
Mr Colin Webster, Senior Network Administrator

Station Operations
Dr Juergen Diekmann, Farm Manager
Mr Bahij El-Kawas, Senior Supervisor – Horticulture

Engineering Services Unit
Mr Koen Geerts, Assistant Director General – Corporate Services*

Purchasing and Supplies (PSD)
Mr Frisco Guce, PSD Manager*
Mr Essam Abd Alla Saleh Abd El-Fattah, PSD Manager**

Personnel Services
Ms Lina Yazbek, Coordinator

Visitors Services
Mr Nabil Trabulsi, Head

Labor Office
Mr Ali Aswad, Consultant, Security Office

International School of Aleppo
Mr Robert Thompson, School Head

Damascus Office/Guesthouse, Syria
Ms Hana Sharif, Head

Beirut Office/Guesthouse, Lebanon
Mr Anwar Agha, Consultant – Executive Manager
Mr Munir Sughayyar, Executive Manager

Terbol Research Station, Lebanon
Mr Munir Sughayyar, Terbol Station Manager

Regional Programs

North Africa Regional Program, Tunis, Tunisia
Dr Mohammed El-Mourid, Regional Coordinator

Arabian Peninsula Regional Program, Dubai, United Arab Emirates
Dr Ahmed Tawfik Moustafa, Regional Coordinator

Oman, Sultanate of Oman
Dr Mohamed Aaouine, Date Palm Specialist*

West Asia Regional Program, Amman, Jordan
Dr Nasri Haddad, Consultant/WARP Coordinator

Nile Valley & Sub-Saharan Africa Program, Cairo, Egypt
Dr Khaled Makkouk, Regional Coordinator

Khartoum, Sudan
Dr Hassan El-Awad, Head

Highland Regional Program – HRP Tehran, Iran
Dr Ahmed Amri, Iran/ICARDA Project Leader

Afghanistan
Dr Syed Javed Hasan Rizvi, Country Manager
Mr Abdul Rahman Manan, Country Liaison Officer, Kabul Office
Dr Ghulam Mohammad Bahram, Agricultural Economist**
Mr Syed Tehseen Gilani, Administrative and Finance Officer

Pakistan
Dr Abdul Majid, Senior Professional Officer

Turkey
Dr Mesut Keser, Consultant – BIGMP

Central Asia and the Caucasus Regional Program – Tashkent, Uzbekistan
Dr Georg Christopher Martius, Regional Coordinator & Head of the CGIAR Program Facilitation Unit for CAC*
Mr Murat Aitmatov, Research Fellow
Mr Yerken Azhigaliyev, Regional Environmental Management Officer**
Dr Raj Gupta, Project Manager (CACILM – SLMR in CAC)*
Ms Madina Musaeva, Junior Scientist**
Dr Nurali Saidov, Research Fellow
Dr Mekhlis Suleimenov, Consultant**
Dr Barno Tashpulatova, Research Fellow

Consultants
Mr Bashir Al-Khouri, Legal Advisor (Beirut)
Mr Tarif Kayyali, Legal Advisor (Aleppo)
Dr Hiroaki Nishikawa, Consultant – Direction
Dr Giro Orita, Honorary Senior Consultant
Dr John Ryan, Consultant**
Dr Ammar Talas, Medical Consultant (Aleppo)

Appendix 7: Acronyms

ACIAR	Australian Centre for International Agricultural Research
AFESD	Arab Fund for Economic and Social Development, Kuwait
AIISWIP	AREO/ICARDA International Spring Wheat Improvement Program
ANAS	Azerbaijan National Academy of Sciences
APRP	Arabian Peninsula Regional Program, ICARDA
AREO	Agricultural Research and Education Organization, Iran
AZRC	Arid Zone Research Centre, Pakistan
BGRI	Borlaug Global Rust Initiative
BOKU	University of Natural Resources and Applied Sciences Vienna, Austria
CABI	CAB International, UK
CAC	Central Asia and the Caucasus
CACRP	CAC Regional Program
CASRII	Central Asian Scientific Research Institute of Irrigation, Uzbekistan
CBE	Commercial Bank of Ethiopia
CDU	Capacity Development Unit, ICARDA
CGIAR	Consultative Group on International Agricultural Research
CIHEAM	Centre International de Hautes Etudes Agronomiques Méditerranéennes, France
CIMMYT	International Maize and Wheat Improvement Center, Mexico
CIP	International Potato Center, Peru
CLIMA	Centre for Legumes in Mediterranean Agriculture, Australia
CWANA	Central and West Asia and North Africa
DARI	Dryland Agricultural Research Institute, Iran
DFID	Department for International Development, UK
ECO	Economic Cooperation Organization, Iran
EIAR	Ethiopian Institute of Agricultural Research
ESE	Ethiopian Seed Enterprise
ETH	Swiss Federal Institute of Technology Zurich
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GCSAR	General Commission for Scientific and Agricultural Research, Syria
GRI	Genetics Resources Institute, Azerbaijan
GTZ	German Technical Cooperation Agency
HCST	Higher Council for Science and Technology, Jordan
IAEA	International Atomic Energy Agency, Austria
ICARDA	International Center for Agricultural Research in the Dry Areas
ICBA	International Center for Biosaline Agriculture, Dubai
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
ICWIP	ICARDA-CIMMYT Wheat Improvement Program
IFAD	International Fund for Agricultural Development, Italy
ILRI	International Livestock Research Institute, Kenya
INIFAP	National Institute for Agriculture, Forestry and Livestock Research, Mexico
INRA	Institut National de la Recherche Agronomique, Algeria/Morocco
IRESA	Institution de Recherche et d'Enseignement Supérieur Agricole, Tunisia
IRRI	International Rice Research Institute, Philippines
ISF	International Seed Federation, Switzerland
ISTA	International Seed Testing Association, Switzerland
IWMI	International Water Management Institute, Sri Lanka
JICA	Japan International Cooperation Agency
KAHEAD	Hawaii-Kurdistan Partnership for Revitalizing Agricultural Higher Education and Development
KARI	Kenya Agricultural Research Institute
MAAR	Ministry of Agriculture and Agrarian Reform, Syria
MAF	Ministry of Agriculture and Fisheries
NAAS	National Academy of Agricultural Sciences, India
NARC	National Agricultural Research Center, Lybia/Nepal
NARI	National Agricultural Research Institute, Eritrea
NARP	North Africa Regional Program, ICARDA
NARS	National agricultural research system
NUFFIC	Netherlands Organization for International Cooperation in Higher Education
NVSSARP	Nile Valley and Sub-Saharan Africa Regional Program, ICARDA
OECD	Organisation for Economic Co-operation and Development, France
OFID	OPEC Fund for International Development, Austria
OPEC	Organization of Petroleum Exporting Countries, Austria
QTL	Quantitative trait locus
SPCFPG	Scientific Production Center of Farming and Plant Growing, Kazakhstan
SPCRI	Seed and Plant Certification and Registration Institute, Iran
SPII	Seed and Plant Improvement Institute, Iran
UNDP	United Nations Development Programme, USA
UNDP/PAPP	UNDP Programme of Assistance to the Palestinian People
UNEP	United Nations Environment Programme, Kenya
UPOV	International Union for the Protection of New Varieties of Plants, Switzerland
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WANA	West Asia and North Africa
WARP	West Asia Regional Program, ICARDA
ZALF	Leibniz Centre for Agricultural Landscape Research, Germany
ZEF	Center for Development Research, Germany

International Center for Agricultural Research in the Dry Areas (ICARDA)
P.O. Box 5466, Aleppo, Syria.
Tel.: (+963) (21) 2213433, 2213477, 2225112, 2225012
E-mail: ICARDA@cgiar.org
Website: http://www.icarda.org

SYRIA – Aleppo (Headquarters)
P.O. Box 5466, Aleppo
Physical address: Tel Hadya, Aleppo-Damascus Highway
Tel: +963-21-2213433
Fax: +963-21-2213490
E-mail: ICARDA@cgiar.org

SYRIA – Damascus
Hamed Sultan Bldg, Abdul Kader Gazairi Street, Malki Area – Tishrin Circle
Tel: +963-11-3331455
Fax: +963-11-3320483
E-mail: damascus@icarda.exch.cgiar.org

AFGHANISTAN
Central P.O. Box 1355, Kabul
Satellite phone: +88-216-21528424
E-mail: icardabox75@cgiar.org

EGYPT
P.O. Box 2416, Cairo
Tel: +20-2-35724358
Fax: +20-2-35728099
E-mail: ICARDA-Cairo@cgiar.org

IRAN
P.O. Box 19835, Tehran 111
Tel: +98-21-22400094
Fax: +98-21-22401855
E-mail: ICARDA@dpimail.net

JORDAN
P.O. Box 950764, Amman 11195
Tel: +962-6-5525750
Fax: +962-6-5525930
E-mail: ICARDA-Jordan@cgiar.org

LEBANON – Beirut
P.O. Box 114/5055, Beirut 1108-2010
Tel: +961-1-813303
Fax: +961-1-804071
E-mail: ICARDA-Beirut@cgiar.org

LEBANON – Terbol
Terbol Research Station, Beka'a Valley
Tel: +961-8-955127
Fax: +961-8-955128
E-mail: ICARDA-Terbol@cgiar.org

MOROCCO
B.P. 6299, Rabat – Instituts, Rabat
Tel: +212-37-682909
Fax: +212-37-675496
E-mail: icardarabat@yahoo.fr

OMAN
c/o Directorate General of Agriculture and Livestock Research
P.O. Box 111, Rumais – Barka 328
Tel: +968 26893578
Fax: +968 26893572
E-mail: m.aaouine@cgiar.org

PAKISTAN
c/o National Agriculture Research Center (NARC), Park Road, Islamabad
Tel: +92-51-9255178
Fax: +92-51-9255178
E-mail: icarda@comsats.net.pk

SUDAN
P.O. Box 30, Khartoum North
Tel: +249-185216178
Fax: +249-185213263
E-Mail: h.el-awad@cgiar.org

TUNISIA
B.P. 435, Menzeh I – 1004, Tunis
Tel: +216-71-752099
Fax: +216-71-753170
E-mail: secretariat@icarda.org.tn

TURKEY
P.K. 39 EMEK, 06511 Ankara
Tel: +90-312-3448777
Fax: +90-312-3270798
E-mail: ICARDA-Turkey@cgiar.org

UNITED ARAB EMIRATES
P.O. Box 13979, Dubai
Tel: +971-4-2957338
Fax: +971-4-2958216
E-mail: icdub@eim.ae

UZBEKISTAN
P.O. Box 4564, Tashkent 100 000
Tel: +998-71-1372169
Fax: +998-71-1207125
E-mail: ICARDA-Tashkent@cgiar.org

YEMEN
P.O. Box 87334, Dhamar
Tel & Fax: +967-6-423951
E-mail: icarda@yemen.net.ye

ICARDA