ICARDA

Annual Report 2005

International Center for Agricultural Research in the Dry Areas

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

Contents

Foreword

The year 2005 was an important milestone in the efforts of ICARDA and its partners in meeting the global challenges of agriculture in dry areas through the application of science. In an assessment of all 15 CGIAR Centers (based on science quality and relevance, impacts, partnerships, and financial and institutional health), conducted by the CGIAR in collaboration with the Science Council and the World Bank, ICARDA was rated "outstanding" - one of only two centers to receive this rating.

To maintain - and even exceed - this level of performance, the Center restructured its research portfolio in 2005. Ongoing research projects were carefully reviewed, and consolidated under six Mega-Projects, focusing on core issues: water management, crop improvement, desertification, crop-livestock systems, poverty and livelihoods, and knowledge dissemination. This consolidation, we believe, will optimize synergies, sharpen our poverty focus, and use the Center's collective skills and resources most effectively.

Monitoring and evaluation is a continuous, ongoing process at ICARDA. Three Center-Commissioned External Reviews (CCER) took place during the year, focusing on specific areas: integrated gene management, natural resource management, and human capacity building. While the report on human capacity building had not been finalized at the time of going to press, the other two CCER reports were extremely positive. However, they did identify some opportunities for improvement; the Center has already begun taking the necessary action to respond to the recommendations of those reports.

Improved varieties remain the backbone of agricultural development efforts. ICARDA's integrated, multi-disciplinary approach to plant breeding continued to pay rich dividends. In 2005, fifteen improved varieties of different crops (wheat, barley, chickpea, faba bean, lentil, forages) were released in countries within and beyond the CWANA (Central and West Asia and North Africa) region.

ICARDA and the United Nations University, Japan, signed an agreement to launch a new South-South partnership to combat desertification. This global network on integrated natural resources management, named 'CWANA-Plus Partnership', will target the vast CWANA region, as well as large parts of China, South Asia, and sub-Saharan Africa. The objectives include sharing expertise and facilities, training developing-country scientists, expanding post-graduate degree programs in integrated land management, and promoting improved practices among small-scale farmers.

ICARDA and CIMMYT, with a common interest in wheat improvement research, have long worked closely together. The two centers further strengthened their collaboration by establishing a joint ICARDA/CIMMYT Wheat Improvement Program for the CWANA region at ICARDA. A Director was appointed to lead the program. Also, the two centers, in partnership with national programs, launched a Global Rust Initiative (GRI) in September 2005 in response to a sudden, large-scale outbreak of a new strain of wheat stem rust. Several countries in East Africa are affected; small-scale farmers in Kenya have lost as much as half their wheat harvest. The CWANA region stands at risk, so immediate action needs to be taken. The GRI embodies all that the CGIAR System stands for – expertise in strategic research, global partnerships, a focus on resource-poor smallholder farmers, and the ability and commitment to react swiftly to challenges.

Nobel Laureate Dr Norman Borlaug, father of the Green Revolution, visited ICARDA headquarters in May 2005 and addressed the "CWANA Wheat Meeting", jointly organized by ICARDA and CIMMYT.

The Center suffered a major blow when Dr Robert D. Havener – one of ICARDA's founding fathers and a mentor to many of our scientists – passed away in August 2005. His memory will continue to inspire us.

The achievements of ICARDA and its partners presented in this Annual Report would not have been possible without the strong support of our donors. We thank them for their trust in ICARDA's work and for their continued support.

Margaret Catley-Carlson
Chair, Board of Trustees

Adel El-Beltagy
Director General

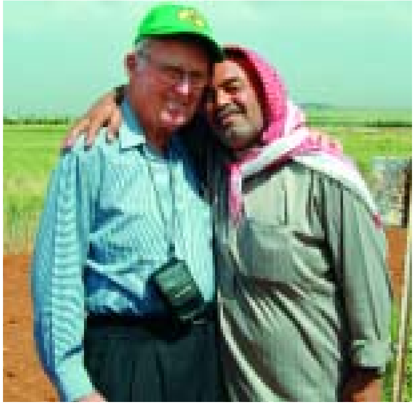
Highlights of the Year

The year 2005 was yet another important milestone in ICARDA's efforts towards fulfilling its global mandate of alleviating poverty and protecting the natural resource base in dry areas. The major achievements reported in this chapter and elsewhere in this Annual Report reflect the collective efforts of the Center, in partnership with national programs, sister centers, advanced research institutes and donors. ICARDA continues to build on these achievements to contribute to the United Nations Millennium Development Goals related to agriculture.

Key events and achievements

Dr Norman Borlaug visits ICARDA

Dr Norman E. Borlaug, Nobel Peace Prize Laureate and father of the Green Revolution, visited ICARDA in May 2005 to address the participants of the "CWANA Wheat Meeting" and review the wheat improvement research in the region. Prof. Dr Adel El-Beltagy, ICARDA Director General, and Dr Robert Havener, former Chair of ICARDA's Board of Trustees, paid tribute to Dr Borlaug for his valuable contributions to agricultural research, spanning six decades.



Farmer Saleh Al-Jaseem hugged Dr Norman Borlaug and thanked him for his contribution to the development of new wheat varieties, when Dr Borlaug visited his field near Aleppo Agricultural Research Center.

Visit to a durum seed multiplication plot in Al-Kam'mari in Aleppo province. Farmer Fayez Abelraz'zak Dandal briefed Dr Norman Borlaug on seed multiplication of wheat varieties released through the Syria/ICARDA collaborative program.

CGIAR Performance Assessment Ranks ICARDA "Outstanding"

In the performance assessment for 2005, conducted by the CGIAR Secretariat and the Science Council, in collaboration with the World Bank, ICARDA emerged as an "outstanding" Center.

Commenting on the good news, Prof. Dr Adel El-Beltagy, Director General of ICARDA, said, "Excellent! I am really delighted to hear this wonderful news. This is the outcome of unwavering efforts of the Board, management team, and all the scientists and other staff of ICARDA."

The following key performance indicators were used, among others, in the assessment: percentage MTP output targets achieved in 2005; Science Council rating of Center outcome statements; SC/SPIA rating of the overall impact assessment; SC/SPIA rating of two impact studies carried out during 2003–05; quality and relevance of current research; institutional health; financial health; staff diversity; and stakeholder perceptions.

Dr Borlaug commended ICARDA for its work in the dry areas. "I can see the tremendous impact that your research and extension has made to increasing food production here in Syria and the neighboring countries," he said.

In his lecture "From the Green to the Gene Revolution: a 21st Century Challenge," Dr Borlaug discussed the Green Revolution, the science behind it, and the factors that contributed to success. He also spoke of the enormous potential of transgenics; and the need for a 'Marshall Plan' for sub-Saharan Africa to provide the basic social and economic infrastructure needed to enable the continent to become self-sufficient in food production.

Looking to the future, Dr Borlaug highlighted the need to double current food production levels to feed the global population in 2050; and, correspondingly, the need to increase output from lands already in production, through a stronger focus on integrated soil health and soil fertility management.

Global Rust Initiative: safeguarding wheat production

The Global Rust Initiative (GRI) was launched in September 2005 at an international meeting in Nairobi, Kenya. It was formed following the disastrous outbreak of a new strain of wheat stem rust, Ug99, first identified in Uganda in 1999. The GRI is an interdisciplinary R&D consortium through which appropriate wheat varieties that possess stable resistance to the new stem rust races will be rapidly developed and deployed.

GRI summit participants. Among those seated in the front row are: Hon. Kipruto Arap Kirwa (fifth from right), Minister of Agriculture, Kenya; Nobel Laureate Dr Norman Borlaug (fourth from right); Prof. Dr Adel El-Beltagy (fifth from left), Director General of ICARDA.

The Initiative is being led by ICARDA and CIMMYT, in cooperation with the Kenya Agricultural Research Institute and the Ethiopian Agricultural Research Organization. Hon. Kipruto Arap Kirwa, Minister of Agriculture, Kenya, inaugurated the launch. Nobel Laureate Dr Norman Borlaug delivered the keynote address.

Wheat stem rust, caused by the fungus *Puccinia graminis*, has caused huge losses in recent decades. In 1950 it destroyed nearly 70% of wheat sown in North America. One strain, first reported in Uganda in 1999, has now spread to other parts of East Africa. Small-scale farmers in Kenya have lost as much as 50% of their wheat; and both Uganda and Ethiopia are severely affected.

The disease now threatens to spread to the Middle East, Asia and the Americas, because the pathogen spores can be transported by wind over long distances. Stem rust control measures will spill over to two other important diseases, yellow rust and leaf rust.

In his opening address at the GRI summit, Prof. Dr Adel El-Beltagy, ICARDA Director General, said ICARDA was pleased to be a partner in the Initiative. He congratulated members of the Expert Panel on the Stem Rust Outbreak in East Africa for their useful report and said "the report forewarns us of the challenges that rusts can bring, and how to forearm ourselves to meet those challenges."

The project has long-term objectives to control the spread of Ug99 globally through a research agenda involving breeding varieties resistant to Ug99; pathogen surveillance, monitoring and early warning system; identification and characterization of new sources of resistance ; capacity building; accelerated seed multiplication; use of fungicides; and knowledge sharing and decision support systems for policy makers.

CIMMYT Board meets at ICARDA

The Board of Trustees of CIMMYT held its annual meeting at ICARDA headquarters in November 2005. ICARDA Board Chair Dr Margaret Catley-Carlson, and Board Chair Elect Dr Guido Gryseels, were present in Aleppo specially to welcome them. The CIMMYT Board toured ICARDA's research facilities and programs, followed by a day of field visits in Hama, Afamia and Homs provinces.

Since the ecoregion served by ICARDA is home to wheat, one of CIMMYT's two mandate crops, the CIMMYT Board was visiting its 'second home'. The two centers collaborate very closely. For example, each holds about 15,000 germplam accessions from the other's collection, duplicated for safe-keeping. A joint ICARDA/ CIMMYT wheat improvement program, in operation since 1980, has led to dramatic production increases in the CWANA (Central and West Asia and North Africa) region.

To further strengthen the partnership, the two Directors General – Prof. Dr El-Beltagy of ICARDA, and Dr Masa Iwanaga of CIMMYT – signed a revised agreement of collaboration during the CIMMYT Board meeting. The new agreement is designed to promote synergy between the two centers and use new modalities to increase the effectiveness and impact of their work.

Dr Alex McCalla (second from left), outgoing Board Chair of CIMMYT, thanked ICARDA for hosting the CIMMYT Board meeting. Seen with him are: Dr Masa Iwanaga (left), DG of CIMMYT; Dr Lene Lang (center), incoming Board Chair of CIMMYT; Dr Margaret Catley-Carlson (second from right), Board Chair of ICARDA; and Prof. Dr Adel El-Beltagy (right), DG of ICARDA.

IFAD team visits ICARDA

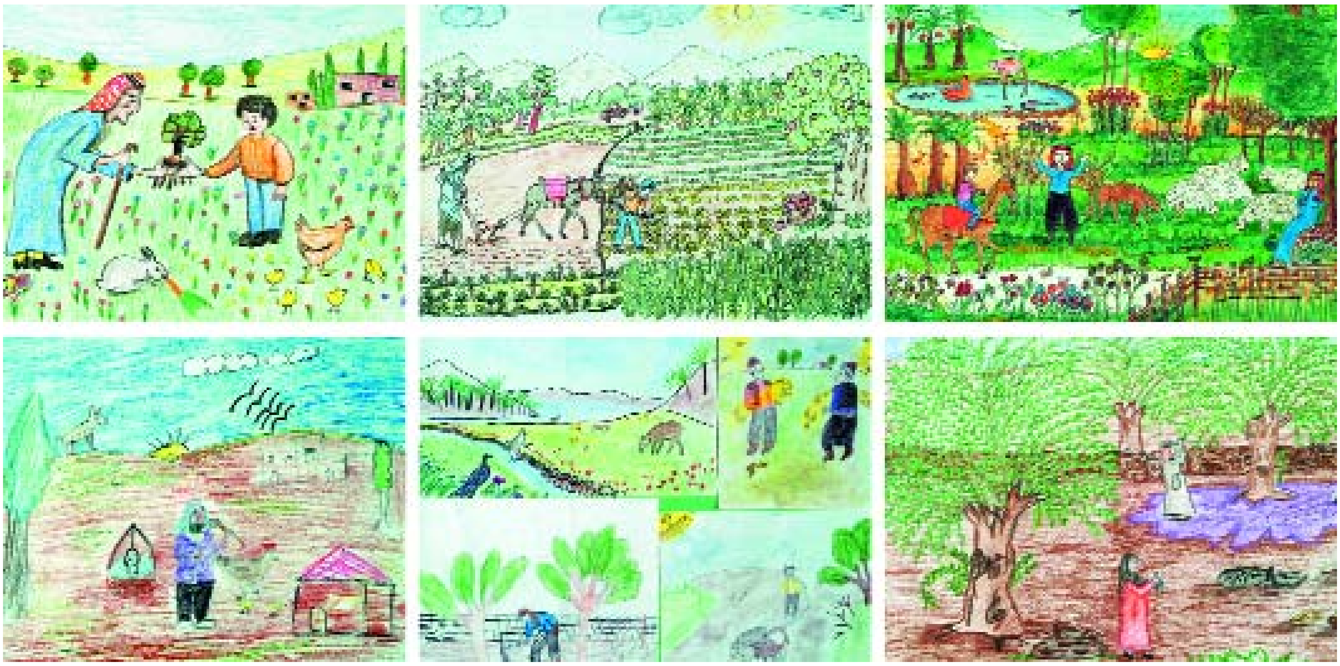
The International Fund for Agricultural Development (IFAD) has been a strong supporter of ICARDA since the inception of the Center. A delegation from IFAD visited ICARDA in May 2005 to review the progress of IFAD-funded projects and discuss future plans. The team, led by Mr James Carruthers, IFAD Assistant-President, Program Management Department, included Ms Mona Bishay, Director, Near East and North Africa Division; Mr Abdelhamid Abdouli, Syria Country Program Manager; and others.

Prof. Dr Adel El-Beltagy, ICARDA Director General, gave the delegation an overview of the Center's work. Directors of the six new Mega-Projects of ICARDA also presented an overview of their respective programs. The IFAD delegation then visited ICARDA's research facilities, and interacted with a number of scientists. Mr Carruthers reaffirmed IFAD's commitment to support ICARDA's research projects.

IFAD delegation, led by Mr James Carruthers (left), IFAD Assistant-President, and including Ms Mona Bishay, Director, Near East and North Africa Division; Mr Abdelhamid Abdouli, Syria Country Program Manager; Ms Mylene Kherallah, Regional Economist; and Ms Annina Lubbock, visited ICARDA's genebank.

Educating children about biodiversity

Biodiversity loss will affect future generations – so it is important that children are made aware of the problem and its ramifications. The Dryland Agrobiodiversity Project, funded by GEF/UNEP and coordinated by ICARDA, worked with the Ministries of Education in Jordan, Lebanon, Palestine and Syria, to promote such awareness. The project organized lectures, field visits and documentary film shows for school children, and distributed



The West Asia Dryland Agrobiodiversity Project helped introduce agrobiodiversity into school curricula in four countries. It also organized a poster competition for children on agrobiodiversity. Here are some of the winning posters.

pamphlets and brochures explaining the causes and potential impacts of biodiversity loss.

As part of this effort, a poster contest was organized for school children in the age group of 10-14 years. Children were asked to create drawings or paintings that reflected various aspects of biodiversity, including crop diversity, degradation, and the role of farmers and communities in traditional agriculture. The paintings clearly showed the huge pool of creative talent, and also the effectiveness of the program in raising awareness. Four paintings were chosen from each country. The winners were taken on a tour of project sites in Jordan, Lebanon and Syria, and awarded T-shirts and other gifts.

National genebank inaugurated in Turkmenistan

During the 8th ICARDA-CAC Regional Coordination Meeting, held in Ashgabat, Turkmenistan, in March 2005, H.E. Begench Atamuradov, Minister of Agriculture, Turkmenistan, along with Prof. Dr Adel El-Beltagy, Director General of ICARDA, inaugurated the national genebank of Turkmenistan.

Mr Atamuradov opened the Coordination meeting. He also delivered a message from the President of Turkmenistan to the participants. "As a result of ICARDA collaboration, there has been considerable progress in Turkmenistan in crop improve-

H.E. Begench Atamuradov, Minister of Agriculture, Turkmenistan, and Prof. Dr Adel El-Beltagy, Director General of ICARDA, opening the national genebank of Turkmenistan.

ment and development of production technologies, e.g. for growing fodder crops on saline soils," said the President in his message.

The meeting brought together 54 participants, including CAC NARS and ICARDA scientists, heads of NARS from the CAC region, a representative from the Asian Development Bank, and H.E. Rejep Saparov, Head of the Office of the President of Turkmenistan.

"Healing Wounds" – how the CGIAR Centers help rebuild agriculture

H.E. Obaidullah Ramin, Afghanistan's Minister of Agriculture, Animal Husbandry and Food, launched "Healing Wounds" in February 2005 in Kabul. Healing Wounds is the report of a study, led by Dr Surendra Varma, Head of Communication and Information Services at ICARDA, of the CGIAR's role in rebuilding agriculture across CWANA, Asia, sub-Saharan Africa, Latin America and the Pacific. The report was produced at ICARDA and published by the CGIAR.

"The Government of Afghanistan is happy that the CGIAR and the Future Harvest Consortium chose Kabul for the main launch of Healing Wounds," said Minister Ramin. "I will personally present a copy to President Hamid Karzai."

Prof. Dr Adel El-Beltagy, Director General of ICARDA, explained the genesis and significance of Healing Wounds and presented examples of the work of the CGIAR centers in Afghanistan, Iraq, Palestine and other countries affected by conflict and natural disasters.

H.E. Obaidullah Ramin (center), Afghanistan Minister of Agriculture, Animal Husbandry and Food, along with Prof. Dr Adel El-Beltagy (right), Director General of ICARDA, and Dr Serge Verniau (left), FAO Representative in Afghanistan, launched "Healing Wounds" in Kabul on 24 February 2005.

"Healing Wounds consolidates the information from the CGIAR centers on rebuilding agriculture. The case studies covered in the report were analyzed to draw lessons that could be used to make the partnerships between research and aid organizations more efficient," he said.

The launch ceremony was attended by a host of dignitaries, including Minister Ramin; H.E. Mohamed Sharif, Deputy Minister of Agriculture; Dr Edwin C. Price Jr., Vice Chancellor of Texas A&M University; and representatives from CIP, CIMMYT, IPGRI, AVRDC, DFID, USAID, FAO, DACAAR, IFDC and Mercy Corps.

The media was well represented as well – BBC, Free Radio Europe, Al-Jazeera TV, Radio Tehran, Chinese News Agency, Internews Afghanistan, Voice of America and many others.

New research portfolio of ICARDA

On 1 January 2005, ICARDA implemented a realigned research portfolio which consolidated its 19 research projects into six Mega-Projects (MPs).

The new portfolio is designed to be a coherent poverty-focused program, to address the key problems of the dry areas, optimize synergy in research, and bring to bear on the Center's collective knowledge, expertise and resources in the most effective and efficient manner possible (see page 10 for more information).

Center-Commissioned External Reviews

A Center-Commissioned External Review (CCER) of ICARDA's natural resource management and socioeconomics research took place from 28 March to 7 April 2005 at the Center's headquarters. The CCER Panel was chaired by Dr Donald Slack, Professor and Head, Department of Agricultural and Biosystems Engineering, University of Arizona, Tucson, Arizona, USA. Dr Patrick Cunningham, Professor of Animal Genetics, Trinity College, Dublin, Ireland and formerly Director of the Animal Production and Health Division at FAO; Dr Fatima Nassif from Institut National de la Recherche Agronomique, Settat, Morocco; and Dr Peter Midmore, Professor of Applied Economics, School of Management and Business, University of Wales, Aberystwyth, U.K., served as Panel members. Dr Kjersti Larsen, ICARDA Board member, served as Observer on the Panel. Dr Slack presented the Panel report at ICARDA on 7 April 2005.

A draft report of the CCER of the Integrated Gene Management program, which commenced in 2004, was presented on 25 April at ICARDA by the Chair of the review Panel, Dr Calvin Qualset, Professor Emeritus, University of California. Prof. Mahmud Duwayri, University of Jordan, formerly with FAO; Prof. Ivan Buddenhagen, Consultant, formerly with the University of California, Davis; and Dr Mogens Lemonius, Consultant, formerly with FAO, served as Panel members.

A CCER of ICARDA's activities in Human Resource Development and Capacity Building of NARS was conducted from 4 to 10 June 2005 at the Center's headquarters. The Panel consisted of Prof. Dr Richard A. Jones, Yale University, USA (Chair); Dr Abderrazak Daaloul, Director General, Agricultural Production, Ministry of Agriculture, Tunisia; and Dr Kausar Malik, Director General, Pakistan Atomic Energy Commission and formerly PARC Chair. Prof. Dr Richard Gareth Wyn Jones, ICARDA Board member, served as Observer on the CCER Panel.

Varieties released in 2005

Crop	Country	Variety name	Other name	Pedigree	Special features
Barley	Ethiopia	Mezezo			Released for short rainy season
		Baso			Released for short rainy season
	Libya	Wadi attba 2			
		Wadi attba 1			
Chickpea	Australia	Nafice		FLIP97-503-CLIMAS	High yielding and disease resistant
		Almaz		FLIP97-530-CLIMAS	High yielding and disease resistant
	Azerbaijan	Narmin	FLIP 95-65C	FLIP85-86C x FLIP86-5C	High yield, *Ascochyta* blight resistance, suitable for early spring planting
	Ethiopia	ICCV-92033			
	Kazakhstan	ICARDA-1	FLIP 96-137C	FLIP91-105C x ILC3385	High yield, *Ascochyta* blight resistance, suitable for early spring planting
	Kyrgyzstan	Rafat	FLIP98-121C x FLIP93-2C	(FLIP90-15C x ILC5362)	High yield, *Ascochyta* blight resistance, suitable for early spring planting
Faba Bean	Ethiopia	PGRC/E 25041-2-2			
Forages	Ethiopia	Wasie	ILAT-LS-LS-B22	ILAT-LS-LS-B22	low β-ODAP, moderately resistant to powdery mildew disease
Lentil	Australia	Boomer	CIPAL 402	ILL 5722 x Palouse	High yield, tall and vigorous growth
		Nipper	CIPAL 203	(Indianhead x ILL 5588) x ILL 5588	High yield, moderately resistant to *Ascochyta* blight and *Botrytis* grey mold diseases
WF Wheat	Kyrgyzstan	Almira	F.474S10.1		

Building partnerships

Challenge Programs

ICARDA is a partner in three of the CGIAR pilot Challenge Programs (CPs):

- *Water and Food*: ICARDA received funding for three projects in this CP through the competitive grants program: two for work on scarce water resources/drought in the Karkheh River Basin, Iran; and one for work on integrated gene management in the Nile River Basin within Eritrea.
- *HarvestPlus*: ICARDA is responsible in this CP for identifying barley and lentil germplasm with high concentration of β-carotene, iron, and zinc.
- *Generation*: ICARDA is a full member of the Generation Consortium and is involved in a series of commissioned research projects and one competitive grant project.

Systemwide and ecoregional programs and other CGIAR initiatives

ICARDA leads the Ecoregional Program for Sustainable Agricultural Development in Central Asia and the Caucasus (ERP-CAC) and continues to participate in Systemwide Programs: Systemwide Genetic Resources Program, Systemwide Livestock Program, Systemwide Program on Integrated Pest Management, Community Action and Property Rights Initiative, Systemwide Soil Water and Nutrient Management Program, Systemwide Program on Participatory Research and Gender Analysis, and the Comprehensive Assessment of Water Management.

ICARDA was co-convener with ICRISAT of a Challenge Program pre-proposal on 'Desertification, Drought, Poverty and Agriculture' that has evolved into 'Oasis' recently and approved as a new Systemwide Program by the Alliance Executive to link Center efforts to combat desertification in support of the UN Convention.

ICARDA is currently the convener of the INRM group of the Alliance Executive. The Center is also an active partner in six projects on Information Technology and Knowledge Management, and leads the project entitled 'Utilization of Intelligent Information Systems for Plant Protection'. ICARDA also participates in a number of other Inter-Center Initiatives including the Consortium for the Spatial Information, International Crop Information System network, activities of the Standing Panel on Impact Assessment, Inter-Center Training Group, and Global Open Food and Agriculture University.

Other collaboration

ICARDA had a joint appointment of a senior scientist with IFPRI until August 2005; the position will be re-filled in 2006. The other joint appointments are: one with IWMI on marginal quality water and the other with ILRI on small ruminant health. ICARDA has a barley breeder posted at CIMMYT, who manages the ICARDA/CIMMYT barley improvement program for Latin America.

ICARDA hosts a senior visiting scientist from CIRAD (Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement), France, and a senior visiting scientist and post-doctoral fellow from JIRCAS (Japan International Research Center for Agricultural Sciences). The Program Facilitation Unit (PFU) of the ERP for CAC, within ICARDA's regional office in Tashkent, hosts an Environment Management Officer supported by the Global Mechanism of the UNCCD and a scientist from AVRDC. Additionally, the PFU houses the Central Asia and the Caucasus Association of Agricultural Research Institutions (CACAARI).

ICARDA's West Asia regional office in Amman, Jordan, houses the secretariat of the regional forum for the Near East and North Africa, AARINENA. The ICARDA Office in Kabul, Afghanistan, houses staff from CIP and formerly staff from IPGRI. In Ankara, Turkey, ICARDA shares an office with CIMMYT. In Pakistan, ICARDA's office provides assistance to CIMMYT and IRRI by managing financial arrangements for their projects in Pakistan.

ICARDA leads the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA) and has formed a similar Consortium to Rebuild Agriculture in Iraq. ICARDA began managing competitive grant funding in 2002/03 under a USAID grant to rebuild agriculture in Afghanistan.

Based on the success of this model, DFID Afghanistan in 2004 contracted ICARDA to manage the Research in Alternative

Livelihoods Fund (RALF). The RALF projects continued in 2005. ICARDA, on behalf of FHCRAA, also manages a USAID-funded project for CIP on potato improvement in Afghanistan. ICARDA manages a Moroccan Collaborative Grant Facility for part of the Moroccan CGIAR contribution.

To supplement its critical mass, ICARDA outsources some of its specific research components to centers of excellence in the region, for example: the Central Laboratory for Computer Expert Systems in Egypt for the development of computer expert systems; the Agricultural Genetic Engineering Research Institute, also in Egypt, for genetic transformation of cereals; and the Institut National de la Recherche Agronomique (INRA) in Morocco for wheat breeding for Hessian fly resistance.

ICARDA harnesses 'new science' through many joint programs with advanced research institutes, which are documented in the project narratives. Cooperative agreements with the private sector span, for example, cooperation in malting barley improvement for the developing world, village-based seed enterprises, and molecular biology. NGOs and development agencies are key partners in linking ICARDA's research to development.

Honors and awards

- His Majesty King Abdullah II bin Al Hussein of Jordan conferred the Al-Istiklal (independence) medal, one of the highest decorations in Jordan, on Prof. Dr Adel El-Beltagy, Director General, in August. H.E. Akel Biltagi, a senior member of the Royal Court of Jordan and Adviser to the King, presented the medal at ICARDA headquarters in August. Also, Prof. Dr El-Beltagy was elected Fellow of the Academy of Sciences for the Developing Countries during the 16th General Meeting of the Academy in Alexandria, Egypt, in November; and Chair of the Global Forum on Agricultural Research (GFAR) in December. As GFAR Chair, he will serve as a member of the CGIAR Executive Committee.
- Dr Raj Paroda, Regional Coordinator, ICARDA-CAC and Head, PFU-CGIAR, received the prestigious Norman E. Borlaug Award for 2005 from the President of India. The award, instituted by the Coromandel Fertilizers, is named after the eminent agricultural scientist and Nobel Laureate, Dr Norman E. Borlaug.
- Dr Ashutosh Sarker, Lentil Breeder, and other members of his team, were honored by the Government of Western Australia in February for their contribution to the development of Ceora, the first low-toxin grass pea variety to be released in Australia. Dr Sarker was also honored by the Bangladesh Agricultural Research Institute for his contribution to pulse research in Bangladesh.
- Dr Mustapha El Bouhssini, Entomologist, was appointed Adjunct Faculty Member in the Department of Entomology at Kansas State University, USA, in December.

On behalf of the ICARDA-Tashkent office team, Ms Ilona Kononenko, Project Administrative Officer, received the CGIAR Science Award for the Outstanding Support Team from Mr Ian Johnson, CGIAR Chair.

- The scientific support team for the CGIAR Program for Central Asia and the Caucasus (CAC) and ICARDA's Regional Program for CAC, based in Tashkent, Uzbekistan, won the "CGIAR Outstanding Scientific Support Team Award." The team consists of Ms Ilona Kononenko, Project Administrative Officer; Ms Madina Musaeva, Research Fellow; Ms Aziza Kalendarova, Office Secretary, PFU-CGIAR; Ms Nadejda Loginova, Junior Office Secretary, ICARDA-CAC; and Ms Nodira Adilova, Secretary to CACAARI.
- The Jordanian National Program presented an award to ICARDA's West Asia Regional Program in April for the fruitful collaborative work on water harvesting techniques and rehabilitation of degraded ecosystems in the *Badia* area of the country.

Tribute to Dr Robert D. Havener, 1930-2005

Dr Robert (Bob) D. Havener, former Board Chair of ICARDA, passed away on 3 August 2005. Bob was a unique combination of the deep and wide knowledge he amassed during his lifetime, the integrity he exuded in whatever he did, the true concern he had for improving the quality of life of the poor, great intelligence and a strong character.

"Bob had a special place for ICARDA in his heart," said Prof. Dr Adel El-Beltagy, Director General. "He was not only one of the founding fathers of ICARDA but also one who guided its development into a 'Center of Excellence' to serve the complex problems of agriculture in the world's dry areas. He strongly believed in the mandate and mission of ICARDA, and was committed to improve the well-being of the poor. He was a mentor and a guide to many staff of the Center. As the Board Chair of ICARDA, he steered the Center with great wisdom and foresight during the period when the whole CGIAR System was undergoing major transformation. Under his stewardship the Center continued to march forward with great confidence. Even after his leaving the Office of the Board Chair, the senior management of the Center continued to turn to him for his wise counsel and guidance".

Dr Margaret Catley-Carlson, ICARDA Board Chair, said: "Bob truly loved ICARDA, the staff and scientists, the good work they do and the zeal they bring to the enormous challenges of agriculture in the dry areas. I had the great honor of succeeding – not replacing – him as Chair of the ICARDA Board: nobody could have replaced him. He was called on to lead, manage and govern great organizations. No room, no meeting, no occasion failed to become a better place when he and Liz were present. He adored and cherished Liz, and her constant traveling with him brought great pleasure to all of us."

Bob Havener last visited ICARDA with the Nobel Laureate Dr Norman Borlaug in May 2005. He took great pride in showing the work of ICARDA to Dr Borlaug. Who could imagine that Bob had come to say farewell to ICARDA and its staff and to have a last look at the Center that he built and nurtured for nearly three decades?

Bob Havener has been taken away from us, but his legacy would always remain with us. His smiling face in his portrait in the "Robert D. Havener Executive Wing" in the administration building of ICARDA, which was dedicated to him on the 26th Presentation Day of the Center in 2003 in appreciation of his outstanding support to ICARDA and the CWANA region, will continue to inspire the entire ICARDA community to move forward on the path of progress shown by him.

May the departed soul rest in peace.

ICARDA's Research Portfolio

On 1 January 2005, ICARDA implemented a realigned research portfolio which consolidated its 19 research projects into six Mega-Projects (MPs). The new portfolio was designed to be a coherent poverty-focused program to address the key problems of the dry areas, optimize synergy in research, and bring to bear on the Center's collective knowledge, expertise and resources in the most effective and efficient manner possible. The MPs are well aligned with the System Priorities for CGIAR Research 2005-2015, and seek to contribute to the UN Millennium Development Goals related to agriculture.

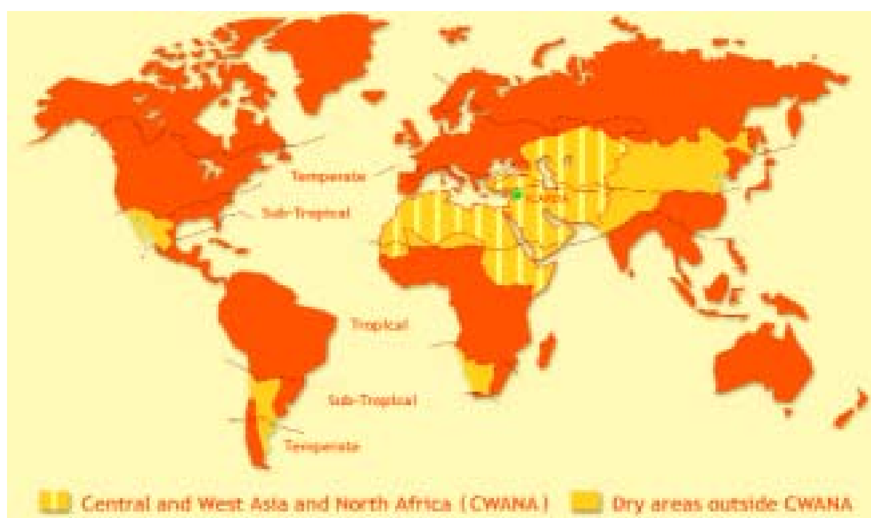
With a multitude of cross-linkages and interactions, the six Mega-Projects are:

Mega-Project 1: Management of scarce water resources and mitigation of drought in dry areas
Mega-Project 2: Integrated gene management: conservation, improvement and sustainable use of agrobiodiversity in dry areas
Mega-Project 3: Improved land management to combat desertification
Mega-Project 4: Improvement, intensification and diversification of sustainable crop and livestock production systems in dry areas
Mega-Project 5: Poverty and livelihood analysis and impact assessment in dry areas
Mega-Project 6: Knowledge management and dissemination for sustainable development in dry areas

The portfolio also includes an ecoregional program entitled "Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus," for which ICARDA is the convening Center.

At the same time, a separate Geographic Information Systems Unit (GISU) was established. GISU superseded the former project on "Agroecological Characterization for Agricultural Research, Crop Management and Development Planning." The specific mandate of GISU is to address ICARDA's growing needs for spatial database development and analysis, and to deliver mapping products, resource databases, methodologies of spatial analysis and agroecological characterization, training, and web portals for knowledge dissemination. In carrying out these activities, GISU is closely linked with MP-1 and MP-3.

MP-1 incorporates research on drought preparedness and mitigation through the optimal management of water resources and use of adapted crops and crop varieties (linking with MP-2 and GISU) and appropriate cropping patterns (linking with MP-4). Greater emphasis is given to the



The global eco-geographic mandate of ICARDA

The eco-geographic mandate of ICARDA covers the dry areas in developing countries globally. The dry areas are characterized by low, unpredictable rainfall, drought, desertification, and acute water scarcity. Environmental resource degradation and human poverty are most pronounced. As a result, rural to urban, as well as international migration is widespread, threatening social, political and economic stability.

The Millennium Ecosystem Assesment Report, published this year, reveals that, globally, desertification threatens over 41% of the earth's terrestrial surface. But it is in these dryland areas that about 2.1 billion people live, about one-third of the global population. Of these dry areas, the Central and West Asia and North Africa—CWANA—region, which includes 35 countries, accounts for the major proportion, about 1.7 billion hectares of land. ICARDA's work therefore focuses on the CWANA region and uses it as the platform to reach other parts of the world to address the problems of dry area agriculture.

dissemination of improved options through integrated and multidisciplinary research (linking with MP-6) and the use of participatory research approaches at the community level at selected benchmark sites (linking with MP-3 on land management). Research on policies and institutions in the project links closely with MP-5.

MP-2 links with MP-1 on water management and drought through genetic research on drought tolerance. Research on genetic enhancement of feed legumes contributes to the integrated crop/livestock production systems in MP-4. Activities on Integrated Pest Management within MP-2 also link with cropping systems research in MP-4. MP-2 links with MP-5 in research targeting and adoption/ impact assessment.

MP-3 has close links with the Center's GIS Unit in the assessment of land degradation. With respect to rangelands, MP-3 focuses on land and vegetation management while MP-4 adds the essential dimension of the management of small ruminants that graze the rangelands and the development of diversification options in these degraded areas. Policy and institutional issues, key to combating land degradation, are addressed in collaboration with MP-5.

MP-4 conducts water-use efficiency work in agronomy and protected agriculture in collaboration with MP-1. Forage legumes and cereal and pulse straws from MP-2 breeding/selection programs are evaluated for nutritive value in the small ruminant program.

Improving rangeland productivity through use of supplements such as feed blocks is carried out in collaboration with MP-3. There is extensive interaction with MP-5, which provides socio-economic input.

MP-5 is integrated with all Mega-Projects and eco-regional programs and contributes to the implementation of socio-economic and policy research, and in adoption and impact studies.

MP-6 is linked with all Mega-Projects in promoting technological, institutional, and policy options for sustainable development.

The new portfolio ensures continuity of previous research activities while accommodating new approaches and new research avenues. These include: improved income generation from high-value crops and by adding value to staple crop and livestock products; rehabilitating agricultural research in conflict or post-conflict situations; and closer alignment of agricultural research with mainstream development programs through research for development applications.

Key Features of ICARDA's Research Stations

ICARDA operates two experimental station sites in Syria, including the main research station at Tel Hadya, near Aleppo, and two sites in Lebanon. These sites represent a variety of agroclimatic conditions, typical of those found in the CWANA region. ICARDA and the Lebanese Agricultural Research Institute (LARI) now share the use of the sites in Lebanon. ICARDA uses these sites for commodity research trials in winter, and for off-season advance of breeding material and for rust screening in cereals in summer.

ICARDA sites in Syria and Lebanon

Sites	Latitude	Longitude	Approx. elevation (m)	Area (ha)	Total precipitation (mm) (2004/05 season)	Long-term average (mm)
Syria						
Tel Hadya	36.01° N	36.56° E	284	948	303.3	349.9 (27 seasons)
Breda	35.56° N	37.10° E	300	95	267.8	275.2 (25 seasons)
Lebanon						
Terbol	33.49° N	35.59° E	890	23	583.5	539.3 (25 seasons)
Kfardane	34.01° N	36.03° E	1080	11	450.2	461.5 (11 seasons)

Mega-Project 1
Management of Scarce Water Resources and Mitigation of Drought in Dry Areas

Introduction

The Management of Scarce Water Resources and Mitigation of Drought in Dry Areas Mega-Project focuses on strategic research on sustainably increasing water productivity, and has expanded its scope from the farm to the watershed and basin level. Partnerships within the Challenge Program on Water and Food and with IWMI have been established to achieve a complementarity whereby ICARDA focuses on assessing and improving on-farm water productivity and IWMI focuses on out-scaling to the basin level. Increased emphasis is being placed on the assessment of scarce water resources, including both fresh and marginal-quality water, and their sustainable allocation to various uses. By linking to other Mega-Projects of ICARDA, Mega-Project 1 integrates research on drought preparedness and mitigation through the optimal management of water resources and use of adapted crops and crop varieties and appropriate cropping patterns. The research and capacity building across the dry areas on developing drought mitigation packages is conducted within a network with FAO, CIHEAM and NARS. The drought network benefits from the intergovernmental system of the FAO and the strong Mediterranean partners of ICARDA and CIHEAM.

Greater emphasis is given to the dissemination of improved options through integrated and multidisciplinary research, and the use of participatory research approaches at the community level at selected benchmark sites. Research on policy and institutions is also included in the Mega-Project 1 portfolio, and implemented across all benchmark projects and activities with a view to model the biophysical and socioeconomic components of the system and develop improved policy and institutional options.

Making wastewater use safer in Syria

Water resource management is especially important in dry areas with fast-growing urban populations. Growing cities such as Damascus and Aleppo in Syria require more clean water while producing larger amounts of domestic and industrial wastewater. To maximize the safe use of wastewater and minimize threats to the environment and human health, ICARDA and IWMI assessed the production, treatment, and use of wastewater in the Aleppo region of the Euphrates-Aleppo Basin.

The Qweik River, which has been polluted with wastewater from Aleppo, Syria. In 2005, researchers from ICARDA and IWMI assessed the production, treatment, and use of wastewater in the Aleppo region, to help maximize the safe use of wastewater and minimize threats to the environment and human health.

Wastewater treatment

Findings show that nearly one-third of Syria's wastewater is treated before it is used for irrigation or discharged into rivers or the sea. In 2006–2007, new wastewater treatment plants will be completed, increasing the amount of wastewater treated by 30% (Table 1).

Wastewater use by farmers

Farmers prefer to use wastewater for irrigation, and researchers found three main reasons for this. The most important, given by 57% of farmers, was the year-round availability of wastewater. The second most important reason (26% of farmers) was the high nutrient content of wastewater, which reduces or even eliminates the need for expensive chemical fertilizers. The third reason (17% of farmers) was that pumping wastewater costs less than pumping groundwater.

Wastewater is used on less than 5% (69,000 ha) of Syria's irrigated land, and treated wastewater is used on only half of this area (37,000 ha). However, although the area irrigated with wastewater is small, it is economically important.

Wheat is the most important crop grown on half the wastewater-irrigated area, followed by cotton, faba bean, and vegetables. Less than 7% of the area under wastewater irrigation is devoted to vegetables, mainly because a 2003 Syrian code of practice prohibits the use of wastewater on vegetables that will be eaten raw.

Table 1. Capacity of wastewater treatment plants in 2005 and of those planned for 2006–2007 in Syria.

Year	Estimated capacity of wastewater treatment plants		% of total wastewater treated
	m^3/day	m^3/year	
2005	978,000	357,000,000	31
2006–2007	1,300,000	475,000,000	41

Table 2. Comparison of the cost-benefit ratio of irrigating with wastewater and groundwater.

Crop	Cost benefit ratio†	
	Wastewater irrigation	Groundwater irrigation
Wheat	5.31	2.34
Cotton	5.17	5.23
Faba bean	5.30	2.93
Vegetables	7.48	3.29

†Calculated as the ratio of gross income to the cost for each crop.

Costs and benefits of wastewater irrigation

A comparative cost-benefit survey in the Aleppo region indicates that when irrigated with wastewater, wheat produces twice as much benefits as when irrigated with groundwater (US$5.31 per US dollar invested, compared with US$2.34; Table 2). Wheat irrigated with wastewater produces higher yields because of the high nutrient content of the wastewater. Farmers also save on the costs of fertilizer (US$95/ha) and pumping.

Irrigation with wastewater does raise concerns about soil and water pollution. However, because no data is available on the background levels of metal and metalloids in Syrian soils, it may not be possible to work out how much contamination is being caused. Contamination is likely, however, because less than half of the wastewater used is treated, and treatment plants are designed to treat domestic wastewater, not industrial wastewater.

Over one-third of farmers know that direct contact with untreated wastewater may affect their health and that of their family members. Data from other sources in two areas where wastewater is used for irrigation—Ghouta, a peri-urban area of Damascus, and the study area in the southern part of Aleppo—showed that 75% of the population suffered from dysentery.

Recommended interventions

The researchers have recommended interventions to maximize the benefits of wastewater irrigation while minimizing the risks.

1. Optimize the performance of wastewater treatment plants
2. Prevent industrial wastewater from entering domestic wastewater treatment plants
3. Encourage industries to treat their wastewater
4. Restrict the disposal of untreated wastewater to stop surface water from being contaminated
5. Monitor harmful contaminants in surface and groundwater
6. Monitor the build-up of chemical pollutants in crops and soils.
7. Enforce the 2003 Syrian code of practice on wastewater treatment and use
8. Evaluate the socio-economic impact of wastewater on farming communities

The study also found that there was a critical shortage of trained Syrian staff to monitor and analyze solid and liquid wastes. Only a few staff have the technical skills to operate, maintain, and monitor industrial wastewater treatment plants. Capacity building is, therefore, needed to enable government staff to implement, on a large scale, new options for wastewater treatment and use.

This is important because responsibilities for the treatment, disposal, and use of wastewater span institutional boundaries. Research leading to new wastewater use technologies could help communities to benefit more while minimizing adverse environmental impacts.

Benchmark sites for water research in the dry areas

There are three major agro-ecosystems in the dry areas: irrigated, rainfed, and marginal rangelands (*badia*). Shortage of water is the key constraint in all these environments. The most critical issue for farmers is how to increase and sustain productivity with limited water. ICARDA has established representative research sites (benchmark sites) in all three agro-ecosystems (Fig. 1).

In partnership with national research systems and rural communities, the Center is using these ‘field laboratories’ to develop and test technological options for improving productivity and sustainable use of water. Benchmark sites for the irrigated, rainfed, and *badia* environments were established in Egypt, Morocco, and Jordan, respectively. Successful technologies will be transferred to other similar agro-ecosystems.

Problems that are not represented in the benchmark sites, but which occur in similar agro-ecosystems elsewhere, are addressed in ‘satellite’ sites in other countries. The satellite sites complement benchmark sites and are used to outscale the results to other areas. The irrigated satellite sites are located in Iraq and Sudan; and the rainfed sites in Algeria, Tunisia, and Syria. The *badia* satellite sites are located in Saudi Arabia and Libya.

Selection and characterization of the *badia* benchmark site

The *badia* climate is harsh, with insufficient rainfall for crop production. The little water available is poorly managed and much of the rainwater is lost through runoff and evaporation. Water harvesting—concentrating runoff for beneficial uses—is perhaps the most promising way of improving productivity in the *badia*. The watershed level was selected as the most appropriate for water-harvesting studies because the techniques will affect both upstream and downstream users.

To select a benchmark site for water-harvesting research in the Jordan *badia*, researchers mapped the boundaries of the main watersheds and sub-watersheds based on contour lines and drainage systems. They identified 226 main watersheds, ranging from 0.3 to

Fig.1. Water benchmark sites in CWANA.

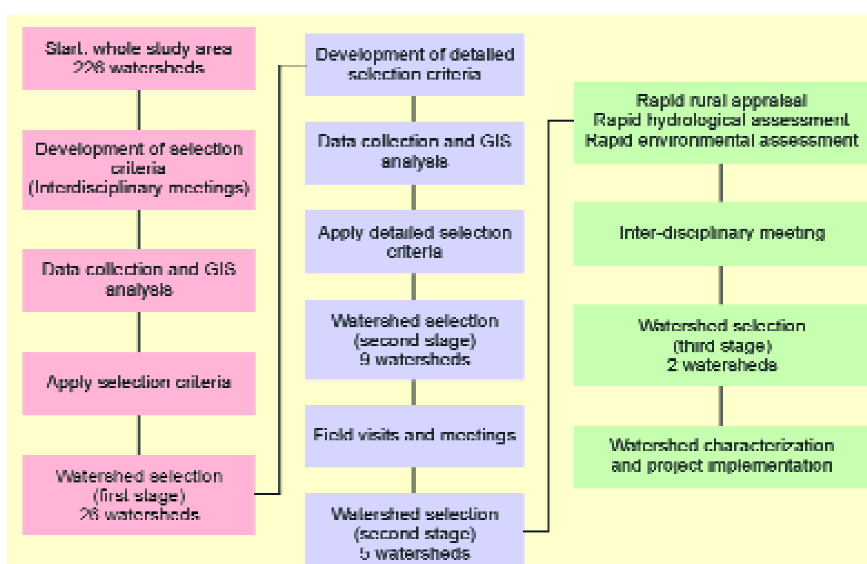


Fig. 2. The benchmark site selection process.

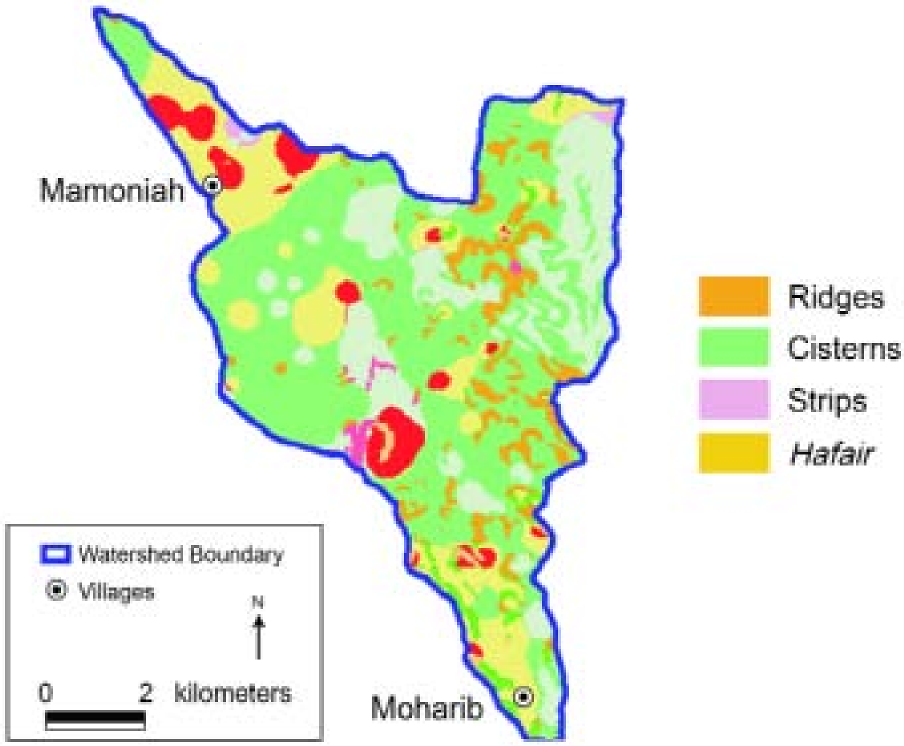


Fig. 3. Suitability map for various water-harvesting techniques in the Moharib watershed, Jordan.

266 km^2 in a zone of 'transitional *badia*' with average annual rainfall of 100–200 mm.

A multidisciplinary team of experts then scored the watersheds using five main selection criteria: rainfall, location of communities, soil type, watershed area, and topography. Forty watersheds scored highly, but 14 of them were excluded because part of their area fell outside the *badia* or crossed international borders. This first-stage selection provided 26 potential watersheds (Fig. 2).

The second stage of selection assessed various criteria, including soil depth, slope steepness, location of communities, land use, watershed size and accessibility, land tenure, and availability of basic data. Plotting data on GIS overlays and superimposing these on the base map of watershed boundaries allowed different experts to visualize and review data and modify the criteria over many rounds of assessment. This process eliminated all but nine watersheds, which were later narrowed to five.

Based on information from stages 1 and 2, the specialists then undertook three types of study: (1) rapid rural appraisal of the socioeconomics of the communities; (2) rapid hydrologic study to assess the suitability of the watersheds for water harvesting; and (3) rapid environmental review to assess the potential impact of water harvesting.

They concluded that two sites would be needed to represent the wide range of biophysical and socioeconomic conditions found in the *badia*. These were the Moharib (the main research site) and Umenaam (a complementary research site) watersheds.

The researchers collected detailed baseline data for the benchmark watersheds and developed suitability maps for various water-harvesting techniques, after consultation with farmers (Fig. 3).

The results indicate that several water-harvesting options (cisterns, ridges, strips, *hafair*, etc.) may work in any one biophysical unit within the watershed. This means that farmers have several options and that other socioeconomic issues can be taken into account when deciding which option to use.

Integrating expert knowledge in GIS to locate biophysical potential for water harvesting: a case study at country level in Syria

Water harvesting covers various techniques to collect rainwater from natural terrain or modified areas and concentrating it for use on smaller sites or cultivated fields to improve crop yields. Few farmers in Syria have adopted water harvesting methods. One reason is that the agricultural research and extension support services in Syria lack specific and systematic knowledge on potential areas and suitable locations for water harvesting. The objective of this study was to provide a rapid GIS-based analytical technique to assess suitability for various water harvesting systems in Syria, with the ultimate objective to adapt the technique for use across the CWANA region.

The assessment was undertaken by matching in a GIS environment simple biophysical information, systematically available at country level, to the broad requirements of the specified water harvesting systems. The systems evaluated include 13 micro-catchment systems, based on combinations of 6 techniques and 3 crop groups, and 1 generalized macro-catchment system.

The environmental criteria for suitability were based on expert guidelines for selecting water-harvesting techniques in dry environments. They included precipitation, slope, soil depth, texture, salinity, land use/land cover and geological substratum. The dataset included interpolated surfaces of mean annual precipitation, the SRTM1 digital elevation model, a soil map of Syria, a land use/land cover map of Syria, and a geological map of Syria.

The evaluation had two stages: scoring of the land attributes according to the individual criteria, followed by the combination of the individual scores in a multi-criteria evaluation. Fuzzy membership functions were used to evaluate suitability for continuous variables, such as precipitation and slope. The functions are fully defined by their shape (either sigmoid or linear) and inflection point positions.

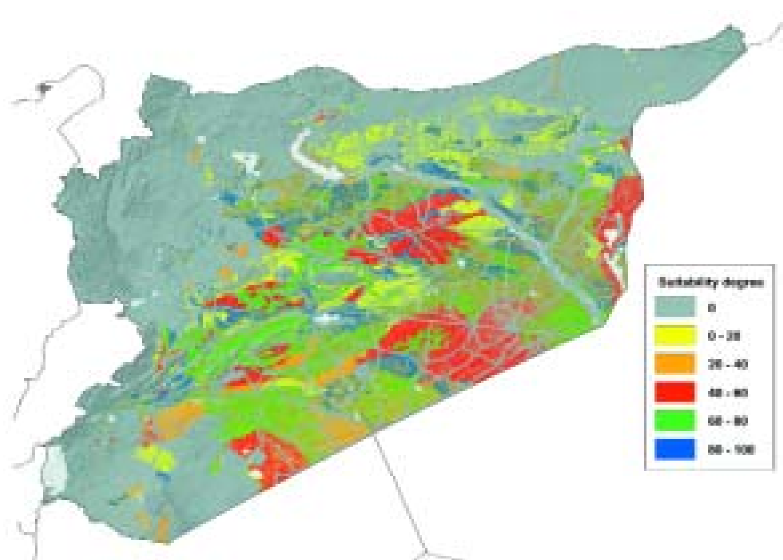


Fig. 4. Suitability map for macro-catchments. Areas in blue are highly suitable as catchments, areas in red highly suitable as target areas; where they occur close to each other, the terrain meets all conditions for a macro-catchment system.

Other relevant factors, such as soils, land use or geological materials, could at the national level only be described qualitatively. In addition, for these datasets it is quite normal that the pixels are not homogeneous but contain mixtures with different properties. Monte-Carlo simulation was used to estimate the approximate proportion of a pixel affected by one constraint or another.

The individual factors were then scored on a common scale (0-100) and combined through the Maximum Limitation Method (MLM) as a special case of Boolean overlay. An example of a suitability map for a micro-catchment water harvesting system is shown in Fig. 4. The scoring is on a scale of 0 to 100.

To identify areas suitable for macro-catchment systems, two separate assessments were undertaken, the first one to evaluate suitability to serve as a catchment, and the second to evaluate suitability as a target area, with the additional condition that the areas should be within a certain distance from each other. The evaluation for catchment suitability included fuzzy membership function for precipitation and slope, in which the scores were adjusted by taking into consideration the soil hydrological properties.

Assessing the potential of groundwater in a drought-prone area

The Khanasser Valley is located on the edge of the Syrian steppe and receives only 210 mm of rainfall on average annually during the cropping season from October to May. Coupled with variation in rainfall from year to year, this means that farming conditions are marginal. Climate change may be adding further stresses to the Valley's agricultural systems. However, the current climate change models cannot be used to assess this, because they do not consider the smaller scale processes that affect local precipitation. ICARDA has therefore been using different methods to assess variability in rainfall, as well as groundwater use and its predicted effects.

Assessing rainfall variation

Trend tests on data from the climate stations in Aleppo and the Khanasser Valley show that rainfall has not decreased in the last 75 years. Although this data does not provide evidence of climate change, limitations in the quality of the data may mask trends.

A view of the Khanasser Valley from the Jabel Al-Hoss plateau, near Aleppo, Syria.

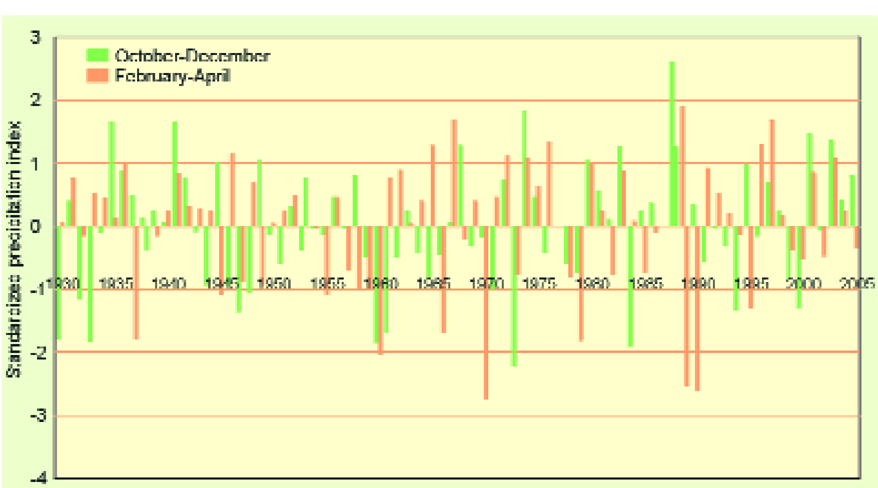


Fig.5. Standardized precipitation index for the Khanasser Valley (1929–2005).

To assess the frequency of drought in the Khanasser Valley, therefore, researchers plotted standardized precipitation index (SPI) values for October to December (planting) and February to April (crop development and flowering) for 1929 to 2005 (Fig. 5). SPI values equal to or less than –1.0 indicate drought.

Farmers often encounter difficult conditions, e.g. wet conditions at planting followed by dry conditions during crop development, or vice versa. During the frequent droughts that affect the area, they often have to leave their villages in search of feed for their flocks or to find work in cities. During the drought of 1958–60, for example, Syria's sheep population was reduced by half and many families migrated to western Syria and Lebanon, and returned only when the drought ended.

Traditional groundwater systems

During drought years, groundwater can supplement rainfall and stabilize crop production. However, groundwater is often also an important source of drinking water for rural communities and their livestock. The Khanasser Valley has a long history of groundwater use. Between the 4th and 7th centuries, and perhaps even earlier, *qanat* systems were dug into the hillside to tap the groundwater. By letting groundwater flow out into the valley through a slightly sloping horizontal tunnel, these *qanats* ensured that no more water was used than could be recharged naturally.

Researchers have found five such *qanats* in the area, two of which dried up in the 1970s when motorized pumps were introduced and groundwater levels fell rapidly. Two other *qanats* had already collapsed earlier. However, in an undisturbed Valley area in the foothills of Jabel Al-Hoss, one small community still uses the water that flows from a *qanat* for its daily needs.

Studies on groundwater recharge

Syria's rural population has more than doubled over the last three decades, and anecdotal evidence suggests that the same is true in the Khanasser Valley. This is putting increasing pressure on groundwater resources. Because rainfall is low and evaporation rates are high, the aquifers receive little replenishment.

Researchers found that present-day recharge mainly takes place on the adjacent Jabel Al-Hoss and Jabel Shbayth basalt plateaus. Analyses of isotopes in water pumped from aquifers in the Khanasser Valley have shown that some of the water used today entered the aquifers more than 3000 years ago.

Predicting the effects of groundwater pumping

Researchers used a numerical flow model (MODFLOW-2000) to investigate the dynamics of the groundwater system in the Khanasser Valley and its response to external influences, such as the introduction of groundwater pumping. The model was calibrated with groundwater-level and flow data from the 1970s—before groundwater pumping began.

These data were supplemented by recent measurements from locations where groundwater levels were not likely to have been greatly affected by pumping. Researchers calibrated the model for a range of recharge values, to allow for any variation in the quality of the available data. Results indicate that average recharge in the study area is just 1% of the long-term average annual precipitation, with an uncertainty range of 0.24% to 2.4%.

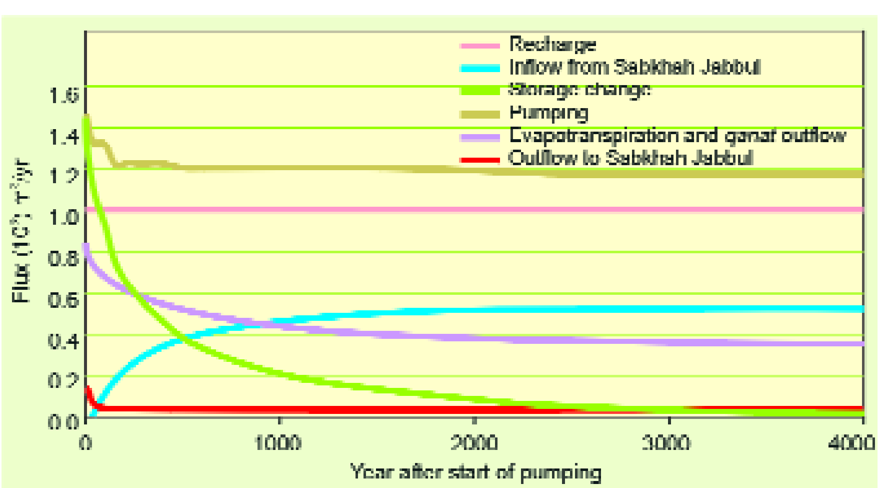


Fig. 6. Simulated changes in flow in the Khanasser Valley groundwater system at the current pumping rates.

Groundwater levels are more vulnerable to changes in pumping rates than to droughts. The results of a 30-year simulation indicated that, without pumping, groundwater levels would generally vary by less than 0.4 m over time. However, at the present pumping rates (1.4 million m^3 per year in average years and 1.2 and 1.7 million m^3 in wet and dry years, respectively) the simulation showed that the water level would fall by 1.4 m on average over 30 years.

The simulation results also showed that after 15 to 62 years of pumping at the present rate, saline water from the Jabbul Sabkhah, a large saline depression north of the Valley, would be drawn into the aquifer. This outcome results from high pumping rates in the Valley bottom, where water is needed for irrigation. But it would take almost 4000 years for the groundwater system to stablize again (Fig. 6).

To find options for sustainable groundwater use in this drought-prone area, researchers modeled various scenarios and found that redistributing production wells—giving each village an equal share—could help sustain higher pumping rates than those of current production wells.

They estimated that villages could pump between 800 and 30,000 m^3 per year. This would provide larger communities with barely enough groundwater to fulfill their domestic needs, though smaller communities would be able to pump some water for their livestock or irrigate small areas of cropland.

Efficient and sustainable use of water in Central Asia

In 2000, ICARDA and national scientists in the Central Asian countries of Kazakhstan, Kyrgyzstan, Turkmenistan, Tajikistan, and Uzbekistan initiated a three-year applied research project on soil and water management with funding from the Asian Development Bank (ADB). The project addressed the major challenges in on-farm soil and water management and aimed to increase agricultural production through maintenance of soil fertility, enhancement of nutrient use efficiency, and improvement of water productivity. The results have demonstrated that adoption of improved technologies could enhance productivity, income, and household food security. It could also contribute to the conservation of natural resources and sustainable agricultural production in the region.

Following the success of the project, a proposal for the second phase was developed, which was approved by the ADB in November 2003. This phase included an expansion of the project to Azerbaijan. The objective was to promote the adoption by farmers of sustainable technological and institutional innovations that conserve soil and water, improve input-use efficiency, and generate greater economic returns. Twenty-two on-farm trial sites were established during the first phase of the project and additional sites in the second phase. Several activities were carried out in 2005 under the project.

At Pobeda and Jambul Agricultural Experimental Station, Kazakhstan, raised-bed planting with cutback irrigation gave higher yield in winter wheat and more efficient use of water than raised-bed planting with furrow irrigation and conventional planting with strip irrigation. Application of ameliorant phosphogypsum to winter wheat and cotton increased water-use efficiency and yield (1.4 kg/m^3 and 3 t/ha when 2.5 t/ha phosphogypsum was applied compared with 0.6 kg/m^3 and 1.8 t/ha with no phosphogypsum). Similar results were obtained for cotton (1.4 kg/m^3 and 3 t/ha with 4 t/ha phosphogypsum compared with 0.6 kg/m^3 and 1.8 t/ha with none).

Winter wheat sown on raised beds in Kazakhstan.

Two irrigation methods, irrigation in sown furrows and contour furrows, were tested in a sloping area of Sokuluk district in Kyrgyzstan. Sowing on beds and furrows with cutback irrigation gave higher water-use efficiency and yield in winter wheat (1 kg/m^3 and 4.1 t/ha) than sowing on beds with furrow irrigation (0.6 kg/m^3 and 2.9 t/ha).

Contour furrows gave higher water-use efficiency in sugar beet. In Tajikistan, several irrigation techniques were tested in persimmon and cotton fields. The drip-jet furrow irrigation produced better height, trunk diameter, and crown size in persimmon than drip-jet irrigation alone, while micro-furrow irrigation produced better growth, number of buds, flowers, and bolls in cotton than conventional furrow irrigation. In Turkmenistan, sprinkler irrigation and alternate furrow irrigation also gave higher water-use efficiency and yields, respectively, in carrot and maize than the conventional furrow irrigation.

In on-farm demonstrations on the benefits of saline soil leaching, cotton produced 2.06 t/ha, 1.36 t/ha and 0.2 t/ha after leaching salts with drain water, blended water and without leaching, respectively. This indicates that leaching can help rehabilitate soils that are affected by high salt content.

In Uzbekistan, the yields of grapevines were 17.72 t/ha, 13.44 t/ha and 12 t/ha, and water-use efficiency was 3.8 kg/m^3 and 2.9 kg/m^3 and 2.1 kg/m^3 under low pressurized drip, drip-jet, and furrow irrigation, respectively. The zigzag furrow recorded higher cotton yield and water-use efficiency (2.6 t/ha and 0.24 kg/m^3) than traditional furrows (2.3 t/ha and 0.21 kg/m^3). The yields and water-use efficiency of winter wheat were higher under sprinkler than conventional furrow irrigation.

Winter wheat gave higher yields and water-use efficiency under furrow irrigation with portable chutes than with no portable chutes. Water-use efficiency and yields in winter wheat, sunflower, maize, sesame, and cotton were higher with the use of fresh water and conjunctive fresh and drain water than with drainage water. Similarly, polyethylene mulch increased water-use efficiency and yield in cotton.

Deficit irrigation: gaining more crop per drop

Despite the shortage of water in the dry areas of CWANA, most farmers still use inefficient irrigation techniques. They irrigate their crops to maximize yields per unit of land. However, using maximum irrigation is unwise and unsustainable in areas where water is scarce and the water table is dropping fast. Maximizing yield per unit of water rather than per unit of land would be a better option.

ICARDA researchers have, therefore, been testing deficit irrigation as one way of increasing water productivity to gain 'more crop per drop'. They have tested deficit irrigation in maize and cotton (two common summer crops) for three years at the Tel Hadya research station.

They found that applying less irrigation water than the amount needed to completely satisfy the crops' water requirements decreased productivity per unit of land, but increased productivity per unit of water.

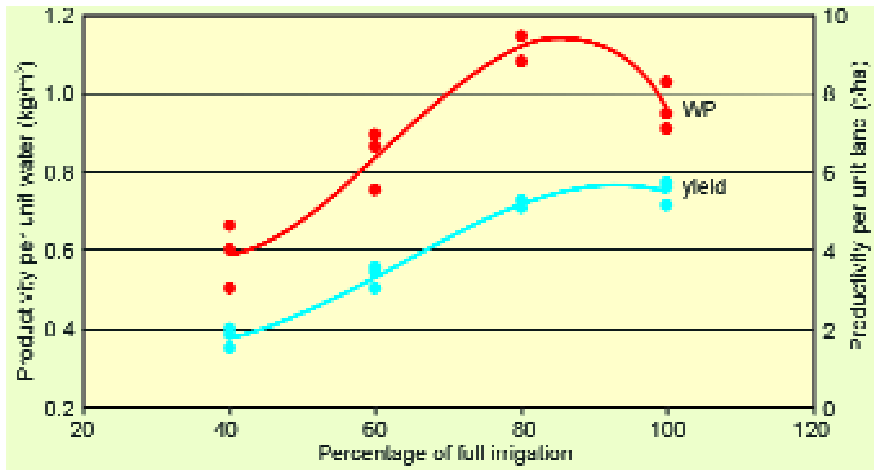


Fig.7. Water productivity and maize yields under different irrigation regimes at Tel Hadya, Syria, 2005.

In the maize trials, for example, reducing irrigation to 80% of the water requirements increased water productivity from 0.9 to 1.1 kg/m^3, but reduced yields only slightly, from 5.7 to 5.3 t/ha (Fig. 7). This indicates that deficit irrigation could save substantial amounts of water. The water saved could then be used to (i) extend the irrigated area, (ii) irrigate higher value crops, or (iii) provide supplementary irrigation for rainfed winter crops.

Although farmers would not produce as much per hectare, irrigating a larger area could increase the total amount produced per

Deficit irrigation trials on cotton at ICARDA Tel Hadya station. Left: Cotton grown under full irrigation (no stress). Right: cotton grown with deficit irrigation (at 40% of full irrigation).

farm. Farm profits would also increase if the additional costs of irrigating more land (such as outlays for labor and new canals or pipes) were lower than the extra benefits from producing more crops.

Using deficit irrigation for winter crops in CWANA would also mean that crops would benefit more from unexpected rainfall during the growing season. This is because deficit irrigation does not saturate the crop root zone, allowing the soil to store rainwater, which is then available to the crop.

The researchers, therefore, suggest a revision of the recommendations for irrigating crops in water-scarce areas. Irrigation practices should take account of the availability and sustainability of water resources in specific basins. ICARDA is working on new guidelines for crop water requirements and irrigation scheduling for the important crops in the dry areas. These new guidelines could help farmers manage limited water supplies, cope with drought, and optimize water productivity and profits.

Mega-Project 2
Integrated Gene Management: Conservation, Enhancement and Utilization of Agrobiodiversity in Dry Areas

Introduction

The Integrated Gene Management Mega-Project seeks to contribute to the improvement of livelihoods of resource-poor farmers through the conservation, improvement, and sustainable use of agrobiodiversity and the development and adoption of improved varieties and associated technologies. The Project is also actively involved in formal and informal seed production systems, policy and institutional research in support of *in situ* conservation of agrobiodiversity, and institutional strengthening and capacity building.

The Project works with more than 200 partners in NARS, advanced research institutions, sister CGIAR centers, and sub-regional and community-based organizations, and is fully involved in the CGIAR Generation Challenge Program and HarvestPlus.

In December 2005, ICARDA and CIMMYT signed a revised Memorandum of Understanding for a joint ICARDA-CIMMYT Wheat Improvement Program in CWANA. This new initiative has helped guide the development of strategies and approaches for wheat networking with the NARS, joint fundraising, and priority setting. It will help align the research agenda of both Centers for CWANA and form better linkages with the NARS. A priority-setting exercise by both Centers will be undertaken in 2006 to incorporate impact pathways in their medium-term plans. The joint project is expected to lead to a higher degree of efficiency in project execution and cost savings through jointly managed offices in CWANA. The Global Rust Initiative, formed by CIMMYT and ICARDA in response to the threat of the new wheat stem rust (Ug99) emerging from eastern Africa, is an immediate outcome of this partnership.

Fulfilling the potential of food barley

Barley (*Hordeum vulgare*) grain can be used to make malt, as well as to provide food for people and livestock. The crop is better able to withstand harsh climates than other cereals. It can also cope better with poor soil fertility and low-input farming systems.

While barley remains a staple food in many of the poorest regions of the world, it is not commonly eaten by people in developed countries. As a result, most barley-breeding efforts have focused on improving cultivars used for animal feed and malting, and not those used for food.

However, food barley cultivars have particular characteristics that consumers like—which means that they cannot simply be replaced by feed or malting barley. Farmers' unique genetic material and indigenous knowledge associated with barley need to be preserved for future generations. ICARDA has, therefore, begun a program to produce better adapted and better quality food barley.

Traditional uses of barley

To guide the food barley improvement efforts, researchers reviewed food barley use around the world. They found a wealth of local recipes, and a large body of knowledge about the health and nutritional benefits of eating barley. Barley grain is used whole, roasted, or cracked. Both roasted and unroasted grain is processed into flour for use in a diverse range of local dishes.

Barley *couscous*, a popular dish in Noth Africa.

Examples of foods derived from barley range from the North African *couscous* and Ethiopian *besso* (roasted barley flour moistened with water, butter, or oil) to *nakia* (a Yemeni drink). Various soups, cakes, and beverages are also popular in high-altitude areas like Tibet and the Andes. In many places, local barley-processing industries have sprung up to satisfy demand.

Barley's health benefits

Over the last 20 years, even in developed countries, barley products have generated great interest because of their high nutritional value. Barley grain, for example, is a good source of beta-glucan (a soluble dietary fiber) and tocols—both of which lower cholesterol. Beta-glucan has also been reported to lower blood glucose levels. As a result, several new recipes based on barley products have been developed.

Barley coffee, a healthy family drink.

Food barley improvement

In response to requests from several national agricultural research programs, ICARDA's Barley Project has begun developing improved food barley cultivars with higher and more stable yields, better grain quality, and greater nutritional value. This work focuses mainly on hull-less germplasm.

Importantly, the screening procedures used in the breeding program do not just consider conventional attributes such as kernel weight, size, color, and protein content. They also take into account characteristics associated with barley's use as human food, such as beta-glucan content, kernel hardness, husk percentage, and cooking time.

Producing nutrient-fortified barley

Another more recent area of research is the production of varieties bred to have an increased mineral and vitamin content. Work on these biofortified crops aims to mitigate the problem of micronutrient deficiency that affects hundreds of millions of people in developing countries, especially women and children. The CGIAR's HarvestPlus Challenge Program is, therefore, working with ICARDA to identify barley germplasm which produces grain with high concentrations of iron and zinc.

In 2005, researchers screened a collection of barley landraces and improved lines. They found that the zinc content of grain varied from 23 to 50 ppm, while the iron content ranged from 26 to 67 ppm. The hull-less barley variety Atahualpa, which has zinc and iron contents of 47 ppm and 55 ppm, respectively, was particularly promising, and will be used to develop micronutrient-dense barley varieties. In areas where barley is already a major part of people's diets, these new varieties will be a source of increased micronutrients.

Promoting participatory plant breeding

In participatory plant breeding (PPB), farmers work with researchers to select and test improved crop varieties. This approach is gaining recognition as an efficient and effective way of improving germplasm. ICARDA uses PPB to develop varieties adapted to drought and the other environmental stresses found in marginal environments, where rural poverty is widespread. The Center uses PPB in more favorable environments as well.

ICARDA has pioneered participatory plant breeding in several developing countries in the Mediterranean (Egypt, Jordan, Morocco, Syria, and Tunisia,) and beyond (Eritrea and Yemen). This has produced a set of methods that will help researchers implement PPB throughout drought-prone regions.

Workshop to promote PPB in the Mediterranean

To encourage scientists in the Mediterranean region to agree on a plant breeding strategy for drought-prone areas, ICARDA convened a Consultative Workshop on Participatory Plant Breeding (CONPAB) in 2005. This was funded by the European Commission and was held at ICARDA's headquarters.

Fifteen scientists from six countries participated—three each from Egypt, Jordan, and Syria, and two each from Algeria, Morocco, and Tunisia. Their expertise covered wheat, barley, lentil, faba bean, and maize, as well as plant breeding, social science, genetic resources, and biotechnology. The workshop built on past germplasm research and the knowledge gained from projects such as "Mapping adaptation of barley to drought environments" (MABDE).

The workshop had three objectives: (i) to create a team of scientists from Mediterranean countries committed to PPB, (ii) to formulate plans for implementing PPB for strategically important crops in the drought-prone areas of the region, and (iii) to disseminate participatory plant breeding methods and strategies.

The workshop program included field visits, meetings with farmers, and lectures by ICARDA scientists and an expert from CIRAD, France. Participants also met with members of various Syrian institutions responsible for research, extension, seed multiplication, and variety release.

The participants developed three proposals for implementing PPB: (i) transform the current breeding program into a participatory program over the next four to five years, (ii) integrate participatory evaluation by farmers into the later stages of the current breeding program, and (iii) develop a participatory program in parallel with the existing breeding program.

The experts attending the workshop also suggested that participatory plant breeding should be introduced into university curricula. Two further recommendations were also made. The first was to involve more scientists in PPB by inviting them to two- or three-day mini workshops in each of the six countries. This could help to institutionalize PPB. The second was to develop a regional project covering key crops and methodologies. Such a regional project could help to foster knowledge-sharing and collaboration.

ICARDA is also working closely with the Mediterranean Agronomic Institute of Zaragoza (IAMZ/CIHEAM). One example of this collaboration is the MABDE research project coordinated by IAMZ/CIHEAM. Funded by the European Commission's INCO-MED program, researchers from Algeria, Italy, Jordan, Morocco, Spain, Syria, and Turkey are working together through MABDE to identify genes that improve drought resistance in barley.


One of the participants, Dr B. Sakr, Plant Breeder, INRA, Morocco, presented an assessment of the workshop. He said that all his colleagues found the workshop useful and are committed to support future PPB activities.

One of the practical outcomes of the workshop was a new PPB project in Algeria. This covers barley in the west of the country and durum wheat in the east. The project will begin in early 2006 with the full support of relevant Algerian institutions.

Developing barley resistant to *Fusarium* head blight

Fusarium head blight (FHB), or scab, reduces barley yields and grain quality by shriveling and discoloring the grain and producing toxins that harm both people and animals. The blight is endemic in Andean countries, southern China and the Midwestern USA, and poses an increasing threat to barley-growing areas around the world. Economically, its impacts are enormous—major epidemics have caused losses of US$750 million in the USA alone since the early 1990s. Since 1980, ICARDA has been working with CIMMYT to produce barley with enhanced resistance to FHB.

Breeding for resistance

The ICARDA/CIMMYT program mainly breeds and tests new germplasm at the Toluca Experimental Station in Mexico, where environmental conditions favor FHB development and its evaluation. More than 2700 lines were tested at Toluca in 2005. The program also collaborates with national programs around the world, distributing high-yielding lines that have good agronomic characteristics and contain a number of sources of FHB resistance.

Since 2000, the program has also been collaborating formally with the United States Wheat and Barley Scab Initiative (USWBSI).

This synchronizes the efforts of researchers from many different programs, ensuring that work is not duplicated and that useful data is generated from a variety of environments. As a result, up to 300 apparently resistant lines produced by ICARDA/CIMMYT are evaluated in early-screening nurseries in the USA each year. The program run by the two Centers also provides enough germplasm for up to 200 research plots at a nursery in China, which the program's researchers visit and evaluate every year.

The team is also involved in the North American Barley Scab Evaluation Nursery, providing up to eight elite FHB-resistant lines per year. As part of this work, the program plants and evaluates a replica of the nursery at Toluca.

Finding new sources of resistance

Sources of resistance to FHB in barley are very rare. So, the program is now conducting a thorough search for new, as-yet-unexploited resistance sources, especially in six-rowed barley. Sponsored by the USWBSI, this work will ensure that all possible sources of resistance are used in future breeding programs.

To this end, ICARDA's genebank is being systematically searched, as it contains a wide range of landraces and wild relatives of barley from CWANA. Potential sources of resistance are being tested at Toluca against local *Fusarium* isolates, to determine whether they show Type I resistance (resistance to fungus penetration) or Type II resistance (resistance to the spread of the fungus in the spike).

A barley grower checks for *Fusarium* infection in his field in Hidalgo state, Mexico.

In 2004 and 2005, for example, the program tested large numbers of previously unscreened lines from the genebank. This yielded more than 590 genotypes with novel genes for resistance to FHB. Many of these genotypes were also resistant to rust diseases (Table 1).

The promising germplasm found will be multiplied so that USWBSI partners can study it using genetic markers. Germplasm found to be genetically distinct from other known sources of resistance will be tested under different environmental conditions worldwide, to see whether the resistance is stable and reliable.

The program also aims to collect as many potentially resistant stocks as possible from other barley improvement programs and gene banks around the world. The program will contact regional breeders from ICARDA and CIMMYT, as well as staff from selected national breeding programs and genebanks, to request new lines of winter and spring barley for genetic marker studies and multi-country testing.

The new FHB-resistant barley varieties produced by the program will be shared freely with developing countries as part of ICARDA's global mandate.

Table 1. Barley nurseries and entries from ICARDA's genebank screened at Toluca, Mexico, and the number of lines found resistant to different diseases.

	No. of genotypes			FHB severity (range across collections)	
Source of germplasm	Resistant to FHB	Resistant to stripe rust	Resistant to leaf rust	Visual score (1-5)†	% grain infected‡
ICARDA genebank	277	45	2	0 - 3	nm
Eritrea collection	295	34	5	nm	1.0 - 28.6
Palestine collection	19	11	nm	2 - 5	3.1 - 34.5

†1 = most resistant, 5 = most susceptible; ‡ Percentage of grains within a spike displaying symptoms; nm = not measured.

Expression of barley genes in response to late drought stress

Barley is often the only rainfed crop that farmers can grow in dry areas. Drought during barley's vegetative growth stage reduces the final grain yield only sightly, but drought during the reproductive stage reduces grain yield significantly.

Past research on the expression of drought tolerance in barley has mainly been conducted using seedlings, and has therefore focused on gene expression during the vegetative growth stage. However, genes that confer drought tolerance are expressed at different growth stages. It is, therefore, important to study drought-tolerance mechanisms at the reproductive stage (i.e. at heading).

Scientists studied barley gene expression patterns at different growth stages and under different water-deficit regimes, using a microarray (Affymetrix GeneChip Barley 1). This knowledge will be used to breed varieties with better yield stability for dry areas.

The study involved two barley cultivars: one drought-tolerant (Tadmor) and the other drought-sensitive (WI2291). In pot experiments, cultivars were grown under a well-watered regime (70% of available water in the soil) until heading. At heading, the plants were divided into three groups according to three moisture-regime treatments: well-watered (70% of available water in the soil), moderate drought stress (35%) and severe drought stress (10%).

These treatments continued until harvest. The grain yields of the three groups were then compared. Researchers also assessed leaf chlorophyll content and chlorophyll fluorescence parameters (e.g. the ratio Fv/Fm) which indicate photosynthetic efficiency.

Physiological and yield traits

Results confirmed field observations that Tadmor is more tolerant to water-deficit stress than WI2291. For example, the chlorophyll fluorescence Fv/Fm ratio fell much less quickly in Tadmor than in WI2291 after researchers applied the drought-stress treatments (Figs. 1a and 1b). The same was true of leaf chlorophyll content (Figs. 1c and 1d). This means that photosynthesis is more efficient in drought-tolerant Tadmor under moisture stress than in drought-sensitive WI2291.

Grain yields of Tadmor in both the drought treatments were reduced to around 80% of the yield in the well-watered treatment. By contrast, yields of drought-sensitive WI2291 in the severe and moderate drought treatments were much lower: only 55% and 60%, respectively, of the yield in the well-watered treatment.

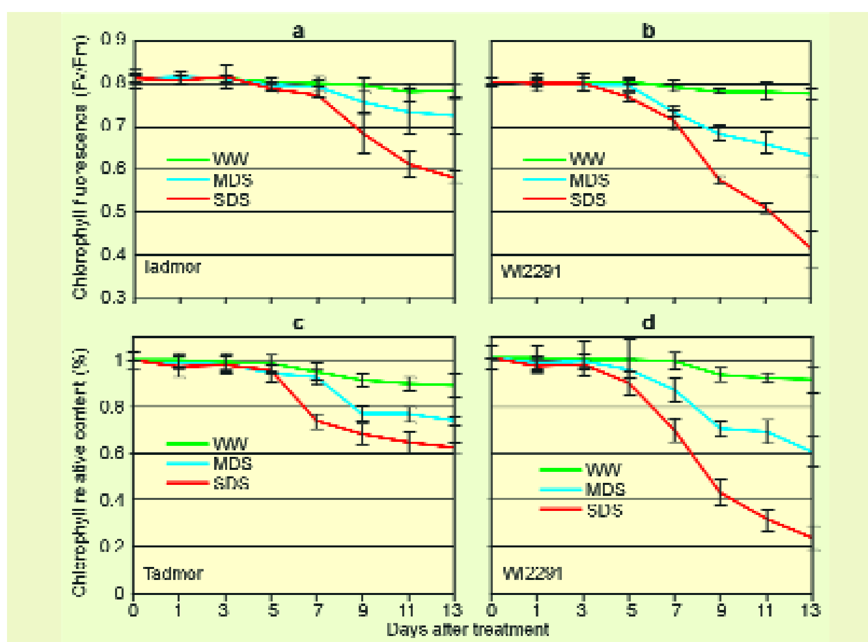


Fig. 1. Indicators of photosynthetic efficiency (chlorophyll fluorescence parameter Fv/Fm and chlorophyll content) in two barley varieties – drought-tolerant Tadmor and drought-sensitive WI2291, under different levels of drought stress. WW=well-watered conditions (70% of available water in the soil), MDS=moderate drought stress (35% of available water in soil), SDS=severe drought stress (10% of available water in soil). Values are the mean and standard deviation of five measurements.

Gene expression

For gene expression analysis (using Affymetrix GeneChip Barley 1 arrays), researchers isolated total RNAs from the flag leaves of Tadmor and WI2291 after flowering. These leaves were collected three days after the moisture-regime treatments had begun, and were taken from the 'severe drought stress' and 'well-watered' treatments.

The results showed that some functional genes in both genotypes respond to water deficit stress similarly in terms of their gene expression profiles: 77 genes were found to be significantly differentially expressed before and after drought in both genotypes. Since they appeared in both the drought-tolerant and drought-sensitive genotypes, these may simply be genes that are expressed in response to drought. They may not actually be responsible for conferring drought tolerance.

Researchers, therefore, further compared the gene expression profiles of Tadmor and WI2291 in response to drought to identify genes that were expressed under drought in only one of the two varieties, not both. In all, 372 genes were found to be significantly differentially expressed between the two genotypes in response to drought after flowering. Some of these may be specific genes that help the plant to adapt to drought stress. ICARDA will study these genes in more depth to identify those that can be targeted by breeding programs.

Breeding drought-tolerant spring bread wheat

Bread wheat breeding at ICARDA is a part of the ICARDA-CIMMYT Wheat Improvement Program (ICWIP) for CWANA.

Bread wheat is the main food for most people in CWANA, where each person consumes 185 kg per year on average. This is the highest consumption rate in the world. However, both productivity and total production of bread wheat are low. Unable to meet increasing demand, most countries in the region have to import substantial amounts of bread wheat.

Spring wheat is grown on at least 11 million hectares in low-rainfall (250-450 mm) semi-arid environments in CWANA, where drought is a major constraint to productivity.

Just under half this area (4.5 million hectares) is planted with bread wheat; the other 6.5 million hectares with durum wheat.

In West Asia, adequate rainfall before anthesis (the period between flowering and seed formation) is often followed by drought during the grain-filling period ('late drought'). Rainfall also often varies greatly between locations, between years, and within each year. For example, over a seven-year period (1998/99 to 2004/05) rainfall at ICARDA's Tel Hadya research station was below average for three years and above average for the other four. Both the total amount of rainfall and its distribution during the year also varied (Fig. 2). Any wheat cultivars grown in such areas, where conditions are highly variable, must have traits that contribute to drought tolerance, high yields and yield stability.

Performance of a drought-tolerant spring bread wheat line (4.5 t/ha) at Tel Hadya under 334 mm annual rainfall conditions, 2005.

To develop improved wheat germplasm with these traits, scientists at ICARDA took regionally-adapted cultivars and landraces and hybridized them with high-yielding advanced lines and synthetic wheats obtained from CIMMYT. They then selected segregating populations under severe drought regimes at Breda (254 mm average rainfall per year) and moderate regimes at Tel Hadya (334 mm per year). The resulting advanced lines were evaluated under five moisture regimes. These ranged from 250 mm to over 600 mm:

i. Breda, rainfed, average rainfall 254 mm;
ii. Tel Hadya, rainfed, average rainfall 334 mm;
iii. Tel Hadya, rainfed plus one supplemental irrigation; 384 mm;
iv. Tel Hadya early planting plus two supplemental irrigations; 450 mm; and
v. Terbol station in Lebanon; over 600 mm.

Researchers chose these locations and moisture regimes in order to simulate variation in water availability in both time and space. The results of the tests were used to select spring wheat cultivars that combine drought tolerance and high yield potential. Fig. 3 shows how the different lines performed under moisture-stressed and favorable regimes. Based on their performance, the lines were classified into four groups (quadrants; Fig. 3). Genotypes in quadrant A are poorly adapted to both moisture-stressed and favorable regimes. Genotypes in quadrant B are specifically adapted to moisture-stressed regimes. They produced above-average yields under moisture stress, but did not perform well in favorable regimes.

The genotypes in quadrant C did well in favorable regimes but performed poorly under stress. By contrast, the genotypes in quadrant D performed well under both moisture stress and favorable regimes—making them input-efficient and input-responsive. These genotypes are adapted to highly variable conditions and give high yields. Such high-yielding, drought-tolerant spring wheat germplasm will play an important role in food security in the CWANA region.

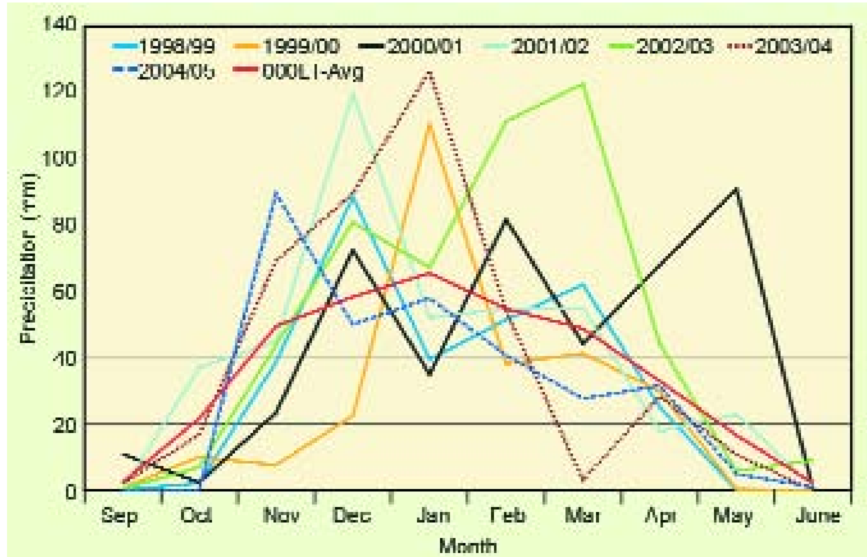


Fig. 2. Variability in rainfall distribution at Tel Hadya, Syria, 1998/99 to 2004/05 cropping seasons. LT-Avg = Long-term average.

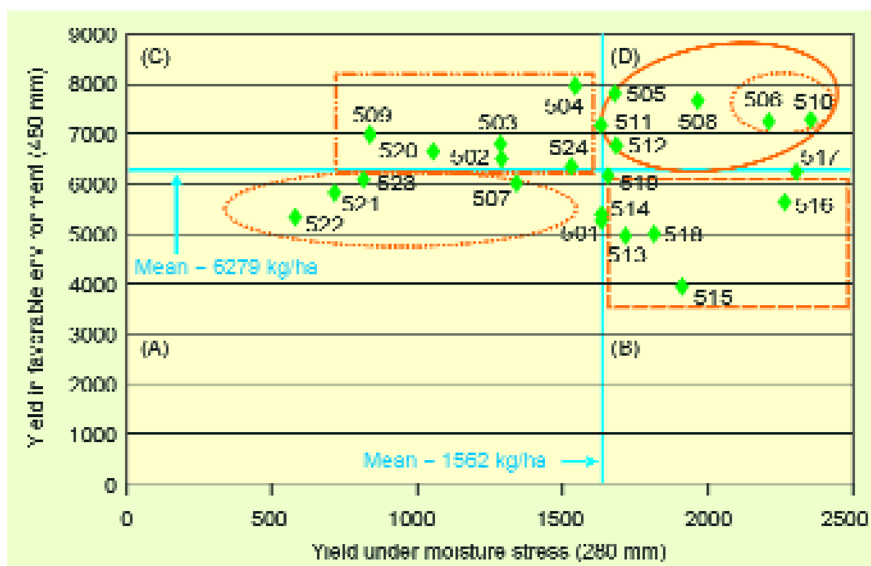


Fig. 3. Yield of new spring bread wheat lines (kg/ha) under favorable and moisture-stressed conditions. Germplasm in quadrant D (top right) is most suitable for use in areas of CWANA where the amount of rainfall varies greatly from year to year.

Exploiting wild relatives in durum wheat breeding

The durum wheat breeding program, like bread wheat, is a part of ICWIP under the joint management of ICARDA and CIMMYT.

In 2005, ICARDA's durum wheat breeding program continued working to understand how wild relatives of wheat tolerate drought and other stresses. Researchers also continued to identify wild species with traits that they can use to improve modern, high-yielding durum varieties.

Wild emmer (*Triticum dicoccoides*), emmer (*T. dicoccum*), Polish (*T. polonicum*), and Persian (*T. carthlicum*) wheats are sources of valuable traits like earliness, grain quality, and disease and drought resistance. ICARDA researchers have shown that several of these wild relatives can maintain their leaf water potential and avoid dehydration even when soil moisture levels are very low. They are able to do this by closing their stomata for long periods and rapidly fixing CO_2. Researchers also found that some of these species can continue to photosynthesize even when drought-stressed—by keeping their photosynthetic enzymes active and their soluble protein and leaf chlorophyll levels constant.

Researchers also tested whether different species could maintain a high relative water content (RWC) in their leaves under drought stress. These included a wild emmer accession (*T. dicoccoides600-808*), and five durum genotypes, including Cham 1 (a drought-tolerant check). Results showed that *T. dicoccoides600-808* and Cham 1 both maintained their relative water content under stress. By contrast, the leaf RWC of the other four durum genotypes fell rapidly as drought stress increased. Researchers also studied three *Triticum* species (*T. polonicum, T. dicoccoides,* and *T. carthlicum*), all of which performed better than *T. dicoccum* and many of the durum varieties tested.

Subsequently, *T. polonicum, T. dicoccum,* and *T. carthlicum* were crossed with the high-yielding improved variety Cham 1. Likewise, *T. dicoccoides600-808* was crossed with the improved variety Korifla. In the resulting crosses, the distribution of the high RWC drought-tolerance trait indicated that inheritance was polygenic (determined by a group of genes) and transgressive. The best performing lines from these crosses were then tested in different environments to assess their grain yield.

Researchers also studied the stress tolerance of *Aegilops* species. Little water was lost from the stomata and epidermis of the leaves of *Aegilops speltoides* and *Ae. geniculata*, indicating drought tolerance. In addition, frost resistance was high in *Ae. cylindrica* and *Ae. geniculata*, but low in *Ae. caudate*, *Ae. comosa* and *Ae. speltoides*, and intermediate in *Ae. triuncialis, Ae. triaristata, Ae. ovata* and *Ae. biuncialis*. This indicates that the U genome present in these species may help to confer cold resistance.

Breeding for stress tolerance and grain quality

To widen durum wheat's genetic base and improve its resistance to biotic stresses (like root rots and insects) and abiotic stresses (like cold and drought), ICARDA scientisits make over 200 crosses per year between improved durum genotypes and *Triticum* wild relatives. The advanced lines and segregating populations produced from these crosses are then selected and screened at different sites and during different seasons to expose them to a variety of stresses.

Winter-sown plants, for example, are screened for resistance to yellow rust, *Septoria tritici*, wheat stem sawfly, cold, and drought. In the winter screening of 2004/05, crosses involving *T. carthlicum, T. dicoccoides*, and *T. monococcum* produced the majority of lines selected for further trials and breeding. Summer-sown plants have to face different stresses, and are therefore screened for resistance to leaf rust, stem rust, heat, and *barley yellows dwarf virus* (BYDV).

In the 2005 summer screening, lines and populations derived from *Aegilops* species, *T. monococcum*, and *T. polonicum* were mainly those selected for future research. This work has produced lines and populations with improved resistance to drought, terminal stress (drought stress at the end of wheat's growing period), yellow rust, root rot, and *Septoria tritici.*

Overall, introducing genes from *T. monococcum* has significantly improved leaf rust resistance, earliness, drought tolerance, and early growth vigor in durum. At the same time, genes from *T. polonicum* and *T. dicoccum* have produced promising advanced lines for hot, dry environments that are resistant to leaf and stem rust and BYDV. Crosses with *T. carthlicum* have produced advanced lines that perform well under cold stress and are resistant to Hessian fly. However, researchers have not been able to introgress resistance to Hessian fly from different *Aegilops* species into durum.

Crosses between dryland-adapted durum genotypes and *T. dicoccoides, T. urartu*, and *Aegilops peregrinacylindros* have generated advanced lines that produce grain high in protein and micronutrients (Fig. 4), yield well in dry areas, and have resistance to both biotic and abiotic stresses. The grain of these new lines is richer in zinc, manganese, copper and iron than that of the improved check variety Korifla (Cham 3).

Overcoming terminal drought stress and improving yield stability

Crosses with *Triticum* and *Aegilops* species have resulted in durum lines that withstand terminal drought stress well. These lines yield much more than the durum landrace Haurani and the durum cultivar Korifla (Table 2). Derived from crosses between durum and *T. araraticum, T. dicoccoides,* and *Ae. columnaris*, they yielded around one ton per hectare more than Haurani. This reflects the progress made in achieving resistance to terminal drought stress.

Trials have also shown that the new lines bolstered by traits from wild relatives give higher grain yields under both dryland (Fig. 5) and high-input conditions. These results also suggest that the drought resistance introgressed from wild relatives is expressed in different environments, and does not reduce the potential for high yields.

Table 2. Grain yield of some durum genotypes derived from crosses with *Triticum* wild relatives under drought and terminal stress conditions in 2005 at Tel Hadya, Syria.

Cross/genotype	Grain yield (kg/ha)	Increase (%) over the local check (Haurani)
Rufom-5/*T.araraticum*500140//Carzio ICD92-0764-WABL-1AP-0TR	2139	101
Sbl1/*T.dicoccoides*600545//Omguer-1 ICD92-0750-WABL-2AP-0TR	1946	83
Haucan/*Ae.columnaris*400020//Omtel1/3/Omlahn3 ICD91-0604-WABL-11AP—4AP-0TR	1939	83
Haucan/*Ae.columnaris*400020//Omtel-1/3/Omlahn3 ICD91-0604-WABL-13AP-5AP-0TR	1936	82
Haurani (local check)	1062	
Korifla (improved check)	1533	44

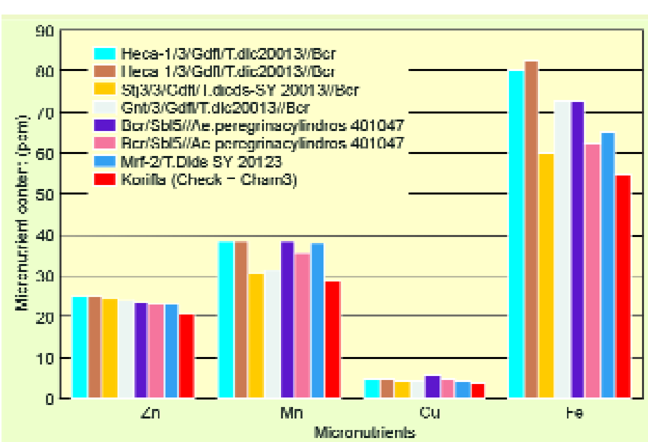


Fig. 4. Higher levels of micronutrients (zinc, manganese, copper and iron) in the grain of seven durum wheat lines derived from crosses with wild relatives (*Triticum* and *Aegilops* species), compared with the check variety Korifla.

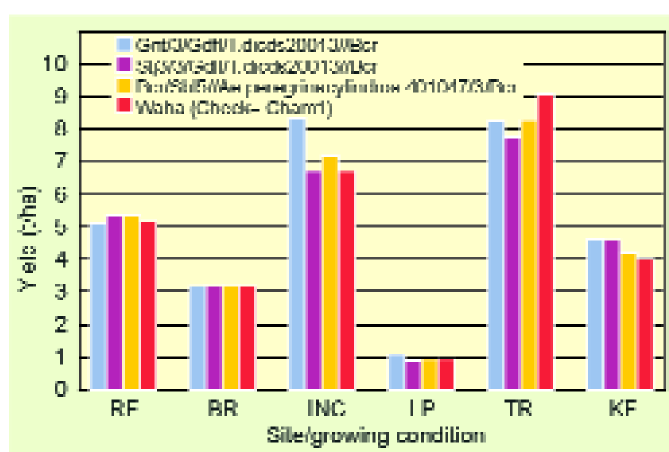


Fig. 5. Using *Triticum* wild relatives to improve durum yield stability: yields at different locations under different growing conditions in 2005. RF: rainfed (Tel Hadya, Syria); BR: Breda, Syria (lower rainfall); INC: favorable (high-input) conditions; LP: late planting (dry and terminal stress), Tel Hadya; TR: Terbol, Lebanon; KF: Kfardane, Lebanon.

High-yielding durum wheat lines derived from crosses with wild relatives

A major aim of the durum wheat breeding program is to produce high-yielding varieties which are adapted to dryland conditions and resistant to the major diseases found in CWANA. Researchers, therefore, crossed the durum wheat cultivar Cham 5 with four wild relatives of wheat. In replicated experiments at Tel Hadya, 17 of the lines yielded more than the durum wheat parent during both a relatively high-rainfall season (2003/04, 400 mm) and a low-rainfall season (2004/05, 300 mm). Importantly, eight of these lines also contain resistance genes for yellow rust and/or leaf rust, inherited from the wild relatives.

All except one of the new lines came from crosses between diploid wild relatives and Cham 5: eight were derived from crosses with *Triticum boeoticum*, six from crosses with *Aegilops speltoides*, and two from crosses with *T. urartu*. Only one high-yielding line came from crosses made with the tetraploid wild emmer wheat *T. dicoccoides*.

The 17 new lines produced (Fig. 6), as well as additional materials derived from wide crosses, will now be tested further by ICARDA and NARS scientists, to assess their performance in different environments across CWANA.

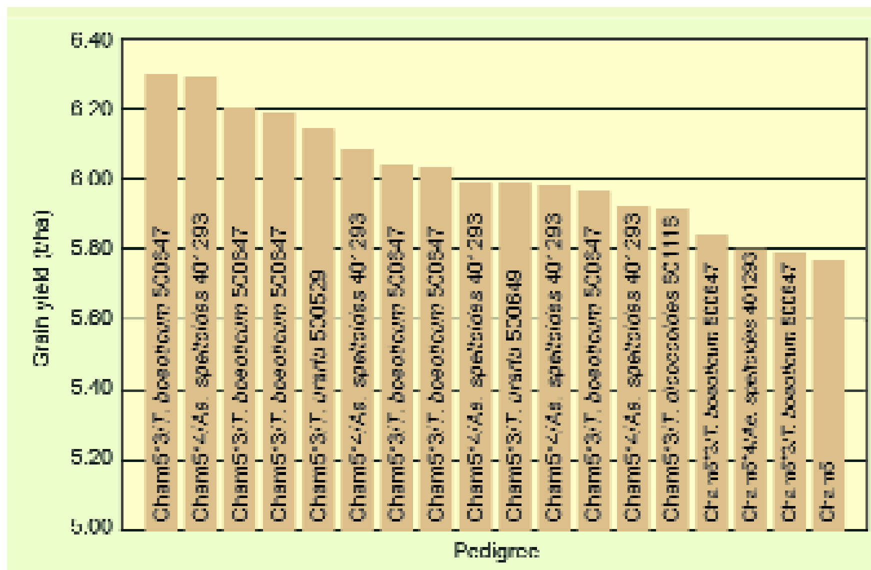


Fig. 6. Durum wheat lines obtained from crossing the high-potential cultivar Cham 5 with various wild relatives of wheat (2004/05). The new lines yield more, and eight contain genes conferring resistance to yellow rust and leaf rust.

Drought-tolerant winter/facultative wheats that yield more when more water is available

This study forms a part of ICWIP under the partnership between CIMMYT, the national research program in Turkey (TAGEM), and ICARDA.

In Mediterranean environments, lack of water severely limits cereal production. Drought-tolerant cultivars that respond well to supplemental irrigation could improve yields in the region.

In partnership with CIMMYT and TAGEM, ICARDA assessed how the grain yields of 25 genotypes of winter and facultative bread wheat (*Triticum aestivum*) varied under different water regimes. The genotypes studied included landraces, released cultivars, and advanced lines.

During trials under nine moisture regimes, mean grain yield decreased as moisture stress increased. Under the lowest moisture regime (302 mm), the average grain yield was 55% lower than under the highest moisture regime (583 mm). Based on the results, the 25 genotypes were classified into four groups (Table 3):

i. non-responsive (GNR) genotypes in which yields did not change in response to different amounts of water;
ii. genotypes that gave low yields under low-moisture regimes but responded to supplemental irrigation (GNDR);
iii. genotypes with high yields under low-moisture regimes which showed a quadratic response relationship under high water inputs (GDRQ); and
iv. drought-tolerant genotypes (GDRL) which showed a linear response to supplemental irrigation.

Fig. 7 shows the mean performance of the genotypes in each of the four groups. Ten of the 25 genotypes displayed both drought tolerance and a good response to supplemental irrigation. Of these 10 genotypes, seven are advanced lines, two are widely-grown varieties, and one is the newly released variety Katia.

The results also showed that the three groups that responded to supplemental irrigation (GNDR, GDRQ, and GDRL) gave significantly higher yields under high-moisture regimes than the non-

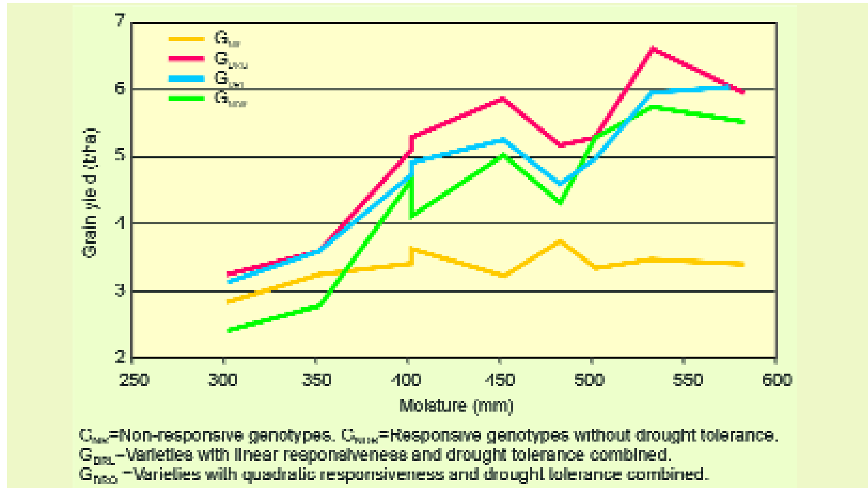


Fig. 7. Mean grain yield of 25 winter and facultative bread wheat genotypes under nine moisture regimes over three seasons (2002/03 to 2004/05) at Tel Hadya, Syria.

Table 3. Grain yield and drought/moisture-response category of 25 genotypes of winter and facultative bread wheat (*Triticum aestivum*) under low and high moisture regimes at Tel Hadya, Syria.

Cross/Name	Origin	Diversity group†	Grain yield (t/ha) Low-moisture regime(302 mm)	High-moisture regime(583 mm)
	Non-responsive genotypes (GNR)			
Azar-2	Iran	NR	3.18	3.12
Son64/4/wr51//mayall/n.th/3/k117	Iran	AL Ir	2.87	3.20
Fen kang15/sefid	Iran	AL Ir	2.68	3.49
Gerek	Turkey	WA	2.60	3.79
Responsive genotypes without drought tolerance (GNDR)				
Sardari	Iran	LR Ir	2.73	3.33
Tjb368.251/buc//anb/buc	Mexico	AL	3.00	6.55
Sdy/ald/3/nai60/hn7//buc/4/alucan	Mexico/ USA	AL	2.19	5.99
Co72.3839/ti-r//fasan/3/co72.3839/ti-r	Mexico	AL	2.43	6.44
Saulesku32/weaver//f4105w2.12	Turkey	AL	2.65	6.06
Ks82w409/spn	USA	AL	2.15	4.94
Agri/nac//Attila	Mexico	AL	2.83	3.88
Vorona/tr810200	Mexico	AL	2.65	6.05
P8-8/llkofen/3/bez/nad//kzm/4/bb//cc/cno *2/3/tob156/bb/5/ning8675	Mexico	AL	1.67	6.46
Kinaci	Turkey	NR	2.55	5.56
Sultan	Turkey	NR	1.64	5.47
Genotypes with drought tolerance and quadratic response (GDRQ)				
Id800994w/vee//f900k/3/pony/opata	Turkey	AL	3.24	5.14
Cham 6	Syria	WA	3.26	6.76
Genotypes with drought tolerance and linear response (GDRL)				
Sbn/1-64-199	Iran	AL Ir	2.75	4.77
Asv/parrot//tam200	Mexico	AL	2.95	6.80
Tam200/mo88//sdy*3/ami	Mexico	AL	3.12	6.39
Vorona/hd2402	Mexico	AL	2.80	5.78
Atay/galvez87	Mexico	AL	3.67	6.05
Agri/nac//kauz	Mexico	AL	2.78	8.16
Katia	Bulgaria	NR	3.98	5.38
Bezostaya	Russia	WA	3.05	5.07
Standard error			±0.23	
Mean			2.78	5.38

†NR = Newly released. LR Ir = Iranian landrace. AL Ir = Iranian advanced lines. WA = widely adapted. AL = Advanced lines from diverse sources with some selection by the Turkey/CIMMYT-ICARDA program.

responsive group (GNR). Under low-moisture regimes, the difference between the groups was not significant.

The linear-response group (GDRL) yielded significantly more than the GNDR genotypes under both high- and low-moisture regimes. The quadratic-response group (GDRQ), by contrast, yielded significantly more than the GNDR group under low-moisture regimes, but not under high-moisture regimes.

The trials showed that the highest yielding genotypes under supplemental irrigation regimes can also be among the highest yielding under fully rainfed conditions. In rainfed marginal environments where rainfall is variable, drought-resistant genotypes that respond positively when it rains, or when supplemental irrigation is applied, provide farmers with a bonus—the additional moisture is immediately translated into higher yields.

A drought-tolerant bread wheat line (left), selected from ICARDA germplasm, compared with a drought-sensitive line (right), at Ardabil Research Station, Iran.

This means that improved lines should combine genetic traits for drought tolerance with traits that boost productivity when moisture becomes available.

Combined resistance to insect pests in wheat and its wild relatives

Sunn pest, Hessian fly, and Russian wheat aphid cause major losses for wheat farmers. Because these pests co-exist in many parts of CWANA, developing improved wheat varieties that combine resistance to all three pests could be a cost-effective and practical method of reducing damage. Wheat lines and their wild relatives were, therefore, screened over one season at ICARDA's Tel Hadya research station to identify those resistant to one or more of these insects.

A researcher examining an accession of *T. monococcum* subsp. *boeoticum* showing resistance to Sunn pest.

The trials involved artificial infestation with the three insects: Hessian fly in the insect-rearing room, Russian wheat aphid in the plastic house, and Sunn pest in cages in the field. Based on the results, researchers identified wild relatives of wheat that were resistant to one or more pests.

An accession from Turkey, IG 44852 (*Triticum monococcum* subsp. *monococcum*), was resistant to both Hessian fly and Russian wheat aphid, and an accession from Syria, IG 118185 (*Triticum monococcum* subsp. *boeoticum*), was resistant to Sunn pest and Russian wheat aphid. Wheat breeders will now use these lines to develop improved varieties with combined resistance to these pests.

Cereal leaf miner: an emerging threat

The cereal leaf miner (*Syringopais temperatella*) is endemic in Jordan. First reported more than 50 years ago, cereal leaf miner seriously threatens wheat and barley crops throughout the country. Most outbreaks in the last seven years have affected crops in the south—the result of drought and a lack of proper crop rotation. However, in the 2004/05 season, an outbreak severely damaged wheat and barley crops in the north.

In April 2005, scientists from Jordan's National Center for Agricultural Research and Technology Transfer (NCARTT) and ICARDA undertook a nationwide survey of wheat and barley crops to assess which areas were affected by cereal leaf miner. Their findings were alarming. About 10% of the fields sown to cereals in the Al Karak Governorate in the south of the country were infested, even though some of them had been sprayed with pesticide by the Plant Protection Directorate. In the north of the country, the Al Ramtha area was severely infested, again despite having been sprayed. Measures to develop integrated pest management strategies to control cereal leaf miner are urgently needed.

Wheat field severely damaged by cereal leaf miner, Al Karak Governorate, Jordan, 2005.

New sources of resistance to cereal cyst nematodes in wheat and barley

Barley and wheat are the most extensively grown cereal crops in CWANA. Wheat alone is grown on over 50 million hectares, largely under rainfed conditions. However, abiotic stresses (mainly drought) and soil-borne diseases limit yields, averaging only 1.5 t/ha. Cereal cyst nematodes are a particular problem, attacking roots, increasing drought stress, and reducing yields by as much as 50%. ICARDA is, therefore, developing ways of controlling the three main species that damage cereal crops in CWANA: *Heterodera avenae*, *H. filipjevi* and *H. latipons.*

Benefits of breeding for resistance

Crop rotation, pesticide use, and other management practices are often used to control cereal cyst nematode (CCN). However, one of the most economically effective and environmentally friendly control measures is the use of CCN-resistant crops. Their use reduces nematode numbers, thus benefiting future crops. They also give higher yields, being able to make

Screening barley lines for nematode resistance at Tel Hadya, Syria.

full use of the water available in the soil because their roots are not damaged.

ICARDA researchers are searching for new resistance genes in cultivated barley and wheat varieties and their wild relatives. These will be used to develop locally adapted varieties with good agronomic traits and resistance to several diseases. The new varieties produced will then be used in tandem with disease-management practices to limit the effects of all the pathogens that might affect the crop.

Screening for resistance

The Center has recently identified promising new sources of resistance to both *H. latipons* and *H. avenae*, the most widely distributed cereal cyst nematodes in CWANA.

The *H. avenae* resistance genes were found by screening 200 cultivars, breeding lines, and wild relatives of wheat and barley (100 accessions per crop). Five different levels of resistance were identified (Fig. 8), allowing researchers to determine the best uses for the different materials (Table 4).

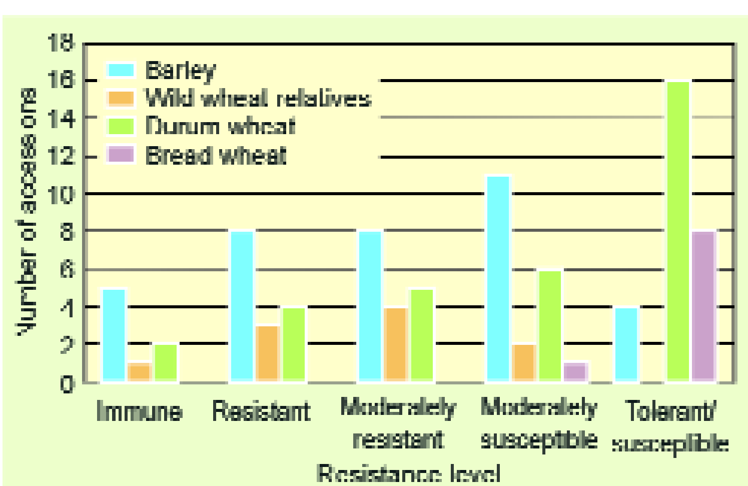


Fig. 8. Levels of resistance to the cereal cyst nematode *Heterodera avenae* found among different types of barley and wheat germplasm at Tel Hadya, Syria.

Immune and resistant germplasm

Researchers found 13 varieties/ lines of barley (including the cultivars Saida and WI2291) which were immune or resistant to *H. avenae*. They also identified six durum wheat accessions that were highly resistant to *H. avenae*. This group included the cultivars Senatore Cappelli, Karim 80, and Ombit-1. No resistant lines were found among the bread wheat accessions tested. However, sources of resistance were found in accessions of the wild wheat relative *T. turgidum* subsp. *dicoccoides,* particularly in those collected in Syria and Jordan. Germplasm in this category will be used in future breeding efforts.

Moderately resistant germplasm

Most of the barley and durum wheat varieties and lines classified as 'moderately resistant' to *H. avenae* are already being cultivated in CWANA. Examples include Arta, Sara-1, and Rihane 03 (barley) and Cham 3, Terbol 97-1, and Cak 97 (durum wheat). These drought-tolerant materials should be further exploited, as their use in CCN-prone areas would eventually reduce the levels of inoculum in the soil. The wild relatives of wheat identified as being moderately resistant to CCN could harbor various sources of resistance, and so could make an important contribution to future breeding programs.

Moderately susceptible germplasm

Researchers identified 11 barley and six durum wheat varieties/ lines as 'moderately susceptible' to *H. avenae*. These include the

Table 4. Levels of resistance to the cereal cyst nematode *Heterodera avenae*, and the recommended use of accessions in each class.

Plant resistance level	Recommended use
Immune: no cysts recovered on test plants (average of 0-1 cyst/plant)	* Use as parental material for gene transfer * Conduct gene pyramiding for durable resistance
Resistant: few cysts recovered (average of less than 10 cysts/plant)	* Use as parental material in breeding program * Introduce to areas with high levels of infestation
Moderately resistant: few cysts recovered on test plants (average of 10-15 cysts/plant) **Moderately susceptible:** more cysts recovered on test plants (average of 15-20 cysts/plant)	* Could be exploited for cultivar development * Use as variety mixture * Could be exploited for cultivar development provided other crop management techniques are used * Use as variety mixture to complement other cultural practices
Tolerant/Susceptible: high numbers of cysts recovered on test plants, but plants do not show typical symptoms (average of less than 25 cysts/plant) **Susceptible:** high numbers of cysts recovered on test plants that show severe symptoms (average of more than 25 cysts/plant)	* Usually associated with germplasm that has high levels of tolerance to other diseases, and could be used in association with appropriate cultural practices * Not recommended for use in CCN-prone areas

barley varieties Zanbaka, Arig 8, Sara, and Harmal, as well as the durum varieties Jori, Oued Zenati, and Gidara-2. Farmers growing these varieties need to use appropriate management practices to avoid yield losses and a build-up of CCN inoculum. So, monocultures and the use of fallows should be avoided. Instead, researchers recommend that farmers growing these crops in CWANA should use a three-year rotation that includes a legume crop and an industrial crop.

Identifying effective resistance to wheat rusts using simple measurements

Virulent pathotypes of yellow rust (*Puccinia striiformis* f. sp. *tritici*), stem rust (*Puccinia graminis* f. sp. *tritici*), and leaf rust (*Puccinia triticina*) are evolving and overcoming the resistance of commonly grown wheat varieties. These fungal diseases threaten wheat production in many parts of Central and West Asia, and could cause large-scale epidemics. ICARDA is therefore working to identify effective resistance genes that breeders can target and use to prevent rust epidemics.

A simple method of measuring disease resistance

To develop effective, practical, and easy-to-use methods of screening for different types of resistance, researchers tested known yellow rust resistance genes against various rust pathotypes in 2005. Plants were artificially inoculated at the Tel Hadya research station. To assess the progress of the disease, researchers monitored the plants for seven consecutive weeks and calculated the average coefficient of infection (ACI) for each week.

The ACI obtained for week 7 was combined with the long-term average of disease records at several different rust 'hot spots' in Central and West Asia. This sim-

Reaction of bread wheat lines to yellow rust at Tel Hadya, Syria. Left, susceptible; Right, resistant.

ple measurement process allowed researchers to plot a disease curve for each gene or combination of genes (Figs. 9 to 11).

The three vertical arrows in Figs. 9 to 11 correspond to (i) the onset of the adult-plant resistance reaction (the arrow at week 2 in each figure); (ii) the optimum expression of adult-plant resistance (the arrow at week 4); and (iii) the final expression of the resistance gene (the arrow at week 6). The horizontal red line in each figure represents a threshold for risk assessment or economic yield loss. Points above that line represent a high risk. Effective resistance (ER) genes that confer good protection at adult growth stages under field conditions (Fig. 9), are those that show a low risk (i.e. an ACI value of less than 0.4) all through the growing season. With these genes, the risk of yield loss is low.

Researchers found that genes such as Yr6+ and Yr7+ (ER1) show a susceptible reaction at the crop's early growth stages, which then falls rapidly (Fig. 9). A similar trend was seen for ER2 (genes YrSD and YrSU), in which there was a rapid increase to a high risk level, then a sharp drop. The following three gene groupings showed consistently good resistance levels and would therefore provide adequate protection to wheat varieties grown in rust-prone areas:

- ER3 (Yr3V)
- ER4 (Yr8 and Yr18)
- ER6 (YrCV, Yr5, Yr3N, Yr15).

Using a combination of all the genes in these three groupings is likely to confer even more effective and long-lasting resistance. However, the effectiveness of such resistance genes needs to be carefully monitored to avoid the sudden breakdown of resistance that can occur when a new pathotype evolves or spreads. ER5 (gene Yr1) is a good example, as a breakdown in the resistance it

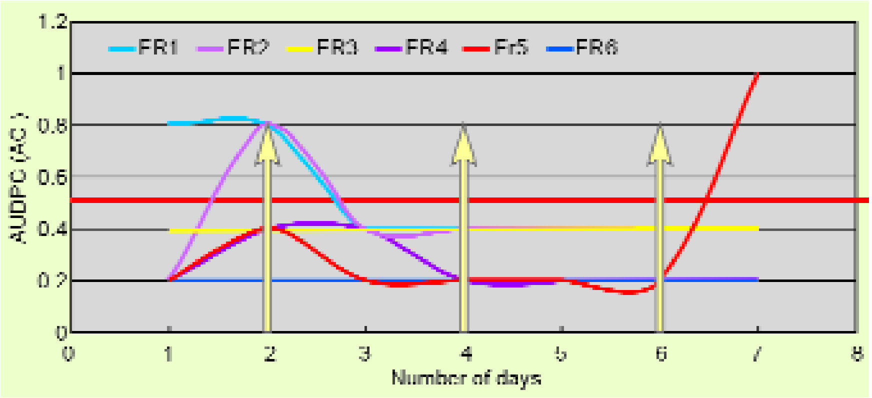


Fig 9. Yellow rust disease progress curves for different combinations of effective resistance genes (ER1 to ER6; see text). AUDPC (ACI) = Area under disease progress curve (average coefficient of infection). Points below the horizontal red line (and especially below 0.4) indicate good resistance.

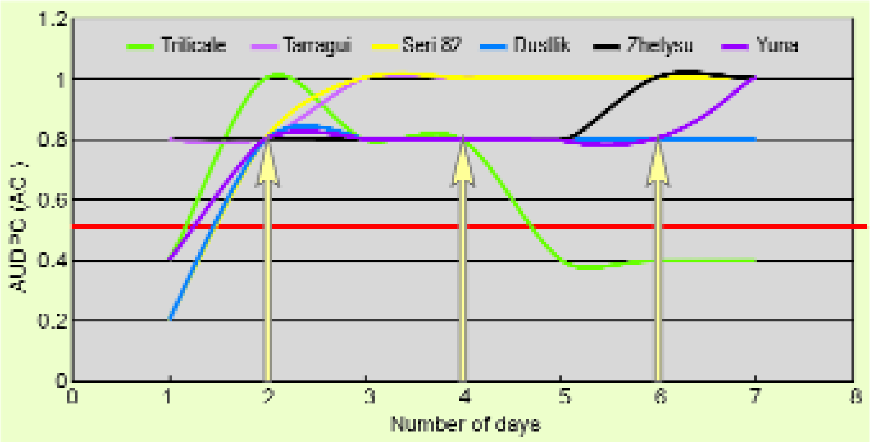


Fig 10. Disease progress curves for wheat cultivars susceptible to yellow rust.

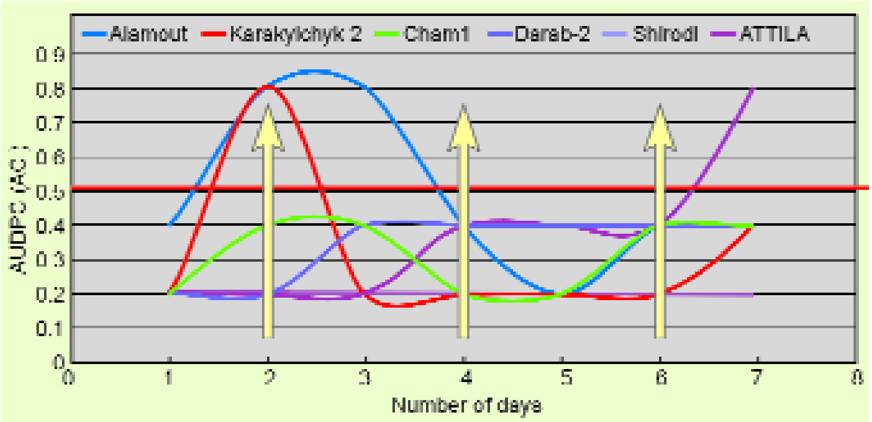


Fig 11. Disease progress curves for commercial wheat cultivars tolerant/resistant to yellow rust.

Table 5. Resistance to three types of rust disease[1] (singly and in combination) of 200 wheat lines inoculated artificially with fungi at Tel Hadya, Syria.

Resistance level	YR, SR and LR	YR and LR	YR and SR	LR and SR	YR alone	SR alone	LR alone
Complete resistance	3	0	14	9	33	18	0
Adult plant resistance	28	7	40	5	20	1	1
Total number of lines	31	7	54	14	53	19	1

[1]Rust diseases: YR = yellow rust; LR = leaf rust; SR = stem rust.
Note: 21 lines were susceptible to all three diseases.

confers was observed in 1999 in Tajikistan, in 2002 in Kyrgyzstan, Kazakhstan, and Uzbekistan, and in 2003 in Syria and Lebanon.

In the case of plants with the Yr1 gene, ACI values recorded at Tel Hadya, as well as those reported from other sites, show that disease development increases rapidly by the seventh week of monitoring (see ER5, in Fig. 9). This means that late-maturing varieties, as well as facultative and winter-planted spring wheats, face a high level of risk. The breakdown of the Yr1 resistance gene is almost certainly the cause of recent epidemics in Central Asia.

Assessing disease resistance in commercial cultivars

Conventional methods of characterizing resistance genes are tedious and time-consuming. Plotting disease curves, by contrast, allows researchers to quickly monitor how effective different genes are against different pathotypes. In 2005, researchers therefore also assessed the types of resistance found in commercial cultivars and elite lines.

The curves obtained for susceptible cultivars (Yuna, Dustlik, Seri 82, Tarragui, and Zhetysu) were all positioned in the high-risk part of the graph following the onset of adult-plant resistance (Fig. 10). Researchers also used a triticale line for comparison, as triticale usually develops adult plant resistance towards the end of the growing season. As expected, this line showed a high rate of infection at the start, which dropped steadily after week 4.

The type of reaction displayed by triticale is highly desirable in Central Asia and the Caucasus, and has been selected for in cultivars newly released in the region (Fig. 11). The Iranian variety Alamout, for example, shows a susceptible reaction type at the start of the season; however, the curve then falls sharply and stabilizes at a low-risk value (an ACI of 0.4). The same trend was seen for Karakylchyk, selected in Azerbaijan. By contrast Attila (Fig. 11) displays the same type of reaction as ER5 (Fig. 9).

Researchers have already used the disease progress curve technique—in combination with artificial inoculation—to characterize the resistance of large numbers of cultivars and elite lines to yellow, stem, and leaf rusts.

Of the 200 bread wheat cultivars already screened, three showed complete resistance, while 28 showed adequate adult-plant resistance to all three rusts (Table 5). In total, 75 accessions (around one-third of those tested) showed combined resistance to two rusts, while another third (70 accessions) showed resistance to a single rust. In fact, around half of the lines tested displayed adult-plant resistance to at least one form of rust.

Selected lines will be further tested under natural infection at hot spots for yellow rust (Azerbaijan, Ethiopia, Lebanon, Iran, Tajikistan, and Yemen), leaf rust (Ethiopia, Lebanon, Kazakhstan, and Morocco), and stem rust (Egypt, Ethiopia, Kenya, Morocco, and Tunisia).

Boosting lentil production in Ethiopia

Lentil in Ethiopia is a major source of dietary protein, and a valuable animal feed. It is often grown in rotation with cereal crops like *tef*, because of its ability to maintain soil fertility. Lentil is a major highland pulse crop in the country's eight agro-ecological zones, with 58,000 ha planted every year. However, average productivity is only 610 kg/ha, compared with the world average of 966 kg/ha. ICARDA has been working with the Ethiopian Agricultural Research Organization (EARO) to develop improved lentil varieties and production technologies. The Center has provided technical support for research and human resource development in collaboration with EARO's Debre Zeit research station, which is responsible for lentil improvement. As a result, there have been significant increases in

A woman farmer in the Chefe Donsa area of Ethiopia grows Alemaya, a lentil variety developed jointly by ICARDA and EARO.

lentil production and exports, as well as in farmers' incomes. This is also contributing to increased nutritional security for the poor.

High-yielding and disease-resistant cultivars

Cultivating stable, high-yielding, and disease-resistant varieties is the key to improved production. Over the last two decades, Ethiopia has released nine improved lentil varieties, seven of which were developed through joint research using ICARDA-supplied germplasm. These varieties are resistant to the major diseases such as rust, wilt, and root rots, and have produced up to 2.6 t/ha in large-scale trials in farmers' fields. They are also well adapted to the highly variable agro-ecological conditions in the country.

Although farmers have not yet adopted all the varieties released, those adopted have been very successful. Adaa and Alemaya, for example, are both popular with farmers. Assano is grown for export, and AlemTina and Teshale produce high and stable yields, with high quality seed characteristics that are valued by consumers at home and abroad.

Delivering technologies to farmers

Technology development is meaningless if the product does not reach farmers. ICARDA has, therefore, been working with agricultural extension agents to ensure that new varieties of lentil, like Adaa and Alemaya, are widely disseminated in Ethiopia. Efforts have included seed multiplication and distribution, large-scale crop demonstrations, field days, and the distribution of leaflets and posters.

As a result, improved varieties are now being grown on around 10,000 ha, producing an extra 4000 tons of lentil per year—worth about US$2 million. The new varieties have been adopted widely in the Chefe Donsa area. Large-scale variety demonstrations have also begun in North Showa, Gonder, and Gossam.

Rural income generation and agro-industries

Increased production and use of the new, large-seeded lentil varieties has created employment for rural communities. Thirty-five to forty lentil splitting and dehulling mills are now operating in north-east Addis Ababa, for example, which process about 20,000 tons of lentil grown in the Showa, Gonder, Wollo, and Tigray regions each year. The improved varieties split better and are less likely to lose their cotyledons during dehulling, which means that more lentil is recovered.

Lentil being sold in an Ethiopian market.

First-grade lentil costs about US$ 550–650 per ton. Because local consumers prefer larger, rounder seeds, the improved Adaa and Alemaya varieties fetch US$400–500 per ton, while the seed of the local cultivars is sold for only US$250–350 per ton. As a result, farmers growing improved varieties can now earn about US$1200 per hectare, which enables them to pay for their children's education, build houses, buy oxen and seed, and open savings accounts.

Biofortification of lentil

The CGIAR HarvestPlus Challenge Program on biofortification of crops has launched a multidonor-supported research program to genetically fortify crops with micronutrients essential for human nutrition. Iron, zinc and vitamin A have been identified as priority nutrients because their deficiency poses a serious threat to health in the poorer sections of society, especially in South Asia and sub-Saharan Africa.

About 3.5 billion people in the developing world suffer from iron deficiency. The primary victims are women and pre-school children. About half a million children go blind every year due to vitamin A deficiency. Hundreds of thousands of people suffer from zinc deficiency, which causes stunted growth, susceptibility to infections, skin lesions, etc. ICARDA, a partner in the HarvestPlus Challenge program, has been involved in the development of bio-fortified crops through genetic manipulation.

Lentil, one of ICARDA's global mandate crops, is one of the 16 target crops in the HarvestPlus Challenge Program. Preliminary analysis of iron and zinc content in more than 1000 lentil accessions, including germplasm, breeding lines and released varieties, has shown tremendous variability among the lentil lines.

This provides the opportunity for breeders to develop micronutrient-dense lentil cultivars. Breeders are using lines that contain high levels of micronutrients for crossing to develop lentils with higher iron and zinc content. Screening for vitamin A content is yet to start.

Some of the cultivars grown by farmers represent a spillover benefit from ICARDA's breeding program for high-yielding and disease-resistant lentil lines. For example, the popular and widely grown lentil variety Alemaya has been found to possess a high content of iron (82 mg/kg) and zinc (66 mg/kg) in Ethiopia. Also, breeders have found a high iron content in Idlib-2 (73 mg/kg) and Idlib-3 (72 mg/kg) in Syria, a high iron and zinc content in Beleza (iron 74 mg/kg and zinc 56 mg/kg) released in Portugal, and a high zinc content in Meyveci-2001 (53 mg/kg) in Turkey. These varieties are helping to reduce micronutrient deficiency in the developing world.

Iron and zinc deficiencies are high in Bangladesh, Nepal, Ethiopia and Morocco, where lentil is a major component of the daily diet of the poor. Therefore, ICARDA has included the NARS of these countries in the project and dispatched the first set of international nurseries to them to select adapted lines. Other developing countries will benefit from the outcome of this research.

Creating a global 'composite set' of lentil germplasm

In 2005, ICARDA took part in a Systemwide program— the CGIAR Generation Challenge Program— that is exploring the genetic diversity in the germplasm collections held by the CGIAR centers. Sub-program 1 of this Program is using molecular microsatellite markers to identify genes for resistance to biotic and abiotic stresses for use in crop improvement programs. A composite set of germplasm, which represents the range of diversity found within each crop, will then be assembled. ICARDA was responsible for creating the lentil composite set.

ICARDA has the global mandate for lentil, and the 10,509 accessions it holds make up the largest lentil collection in the world. This includes 8789 accessions of cultivated lentil from 70 countries, 1146 ICARDA breeding lines, and 574 accessions of six wild *Lens* taxa collected in 23 countries (Fig. 12). From this collection, researchers compiled the final composite germplasm set of 1000 accessions. To do this, ICARDA researchers first chose 7345 FAO-designated landrace accessions, which could be distributed without restriction and had enough seed for distribution. Representatives from the

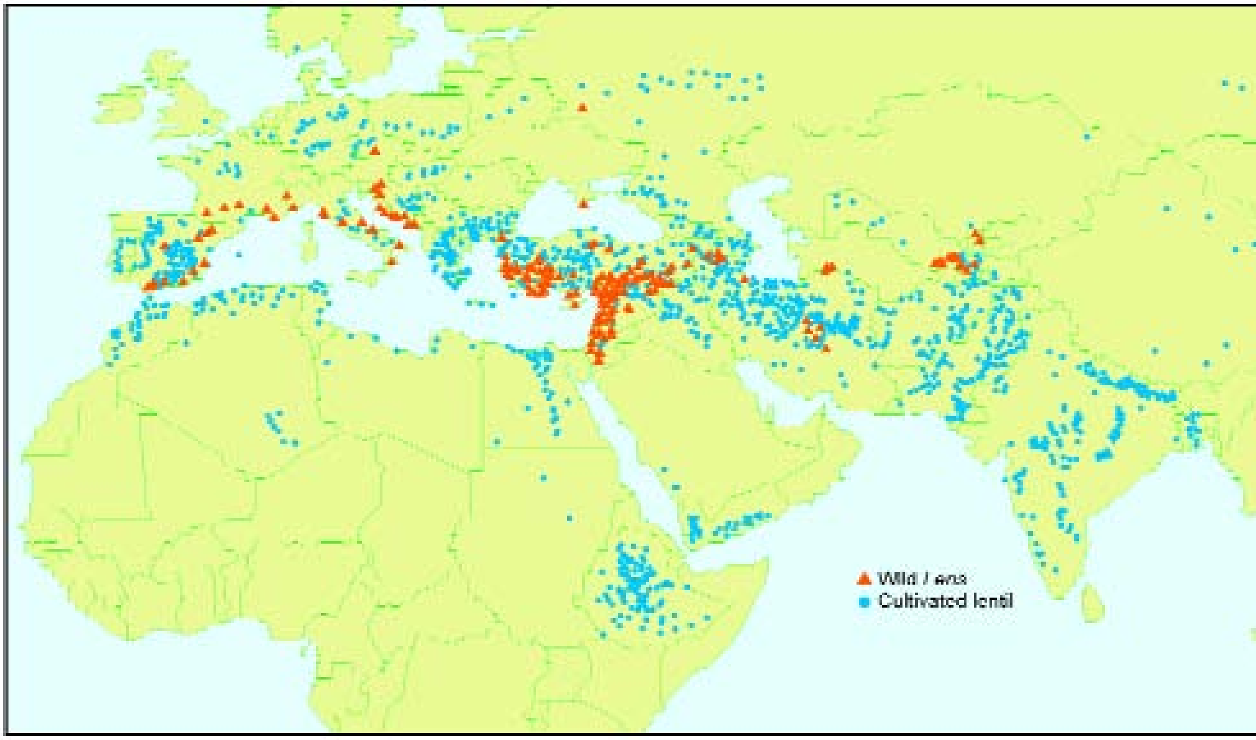


Fig. 12. Global distribution of ICARDA's lentil collection.

three putative wild progenitors of cultivated lentil, including 238 wild *Lens* accessions from 12 countries, were also chosen in this first step.

Researchers then conducted hierarchical cluster analysis based on the geographic origins of the accessions. The evaluation data for five years were first separated into five main datasets. They were then separated by geographic location, giving 50 datasets. Researchers then used 16 morphological and agronomic characteristics in a hierarchical cluster analysis to select approximately 10% of the accessions at random for inclusion in the composite set.

To ensure that the full agroclimatological range for lentil was represented, researchers also used a two-step cluster analysis. The analysis was based on 66 types of agriculture- and climate-related data, which were linked to the geographical coordinates of the collection sites of the accessions. Two hundred clusters were produced, and one accession was selected randomly from each for inclusion in the composite set, if it was not already represented by the previous method.

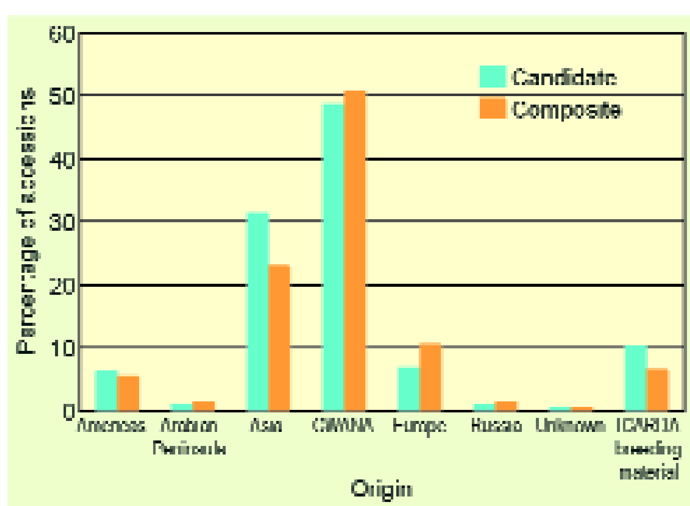


Fig.13. Geographical origins of the lentil accessions selected for inclusion in the composite set of lentil germplasm. This set will be used to find valuable genes for crop breeding. The origins of the composite set reflect those of the entire ICARDA collection.

In addition, 64 accessions of landraces, breeding materials, and already-released cultivars were included in the set. These had resistance to a number of stresses, including high temperature, drought, boron deficiency, lodging, rust, *Fusarium* wilt, downy mildew, and *Ascochyta* blight. Eighteen wild *Lens* accessions were also included because they contained valuable resistance to drought, cold, wilt, and *Ascochyta* blight.

The composite set produced by ICARDA is representative of the entire ICARDA lentil collection, in terms of both geographical distribution (Fig. 13) and type of material. For example, landraces make up around 80% of both the ICARDA collection and the composite set. Likewise, levels of genetic diversity (in both agronomic and morphological traits) are similar in both the composite set and the larger ICARDA collection. Seed of all accessions included in the composite set has already been planted at ICARDA. DNA will be extracted from the growing plants to study the micro-satellite diversity using 30 simple sequence repeat (SSR) markers.

Identifying micro-satellite markers to improve resistance to *Fusarium* wilt in lentil

In recent years, ICARDA researchers, in collaboration with the University of Kiel, Germany, have made steady progress in mapping the lentil genome. Now, they have identified micro-satellite markers that will help them tag the gene for resistance to *Fusarium* vascular wilt—one of the most damaging diseases of lentil.

Researchers successfully localized the *Fusarium* resistance gene on linkage group 6 (LG 6; Fig. 14). This gene is flanked by micro-satellite marker *SSR59-2B* and amplified fragment length polymorphism (AFLP) marker *p17m30710*, at 8.0 cM and 3.5 cM, respectively. The *SSR59-2B* marker and further fine mapping of the locus will greatly help researchers breed lentil genotypes resistant to *Fusarium* wilt.

The micro-satellite markers identified in this study are highly polymorphic and locus-specific. Most are also co-dominant. This type of marker is particularly useful for differentiating homozygous and heterozygous genotypes. In marker-assisted breeding (both in selection and back-cross breeding) co-dominant markers help identify homozygous genotypes at an early stage in selection. Until recently, no such co-dominant markers had been identified in lentil. This is why the co-dominant markers identified in this study will be so important in breeding *Fusarium*-resistant lentil genotypes. Future research should aim to identify further micro-satellite markers to tag genes that will improve lentil productivity.

Lentil damaged by *Fusarium* wilt.

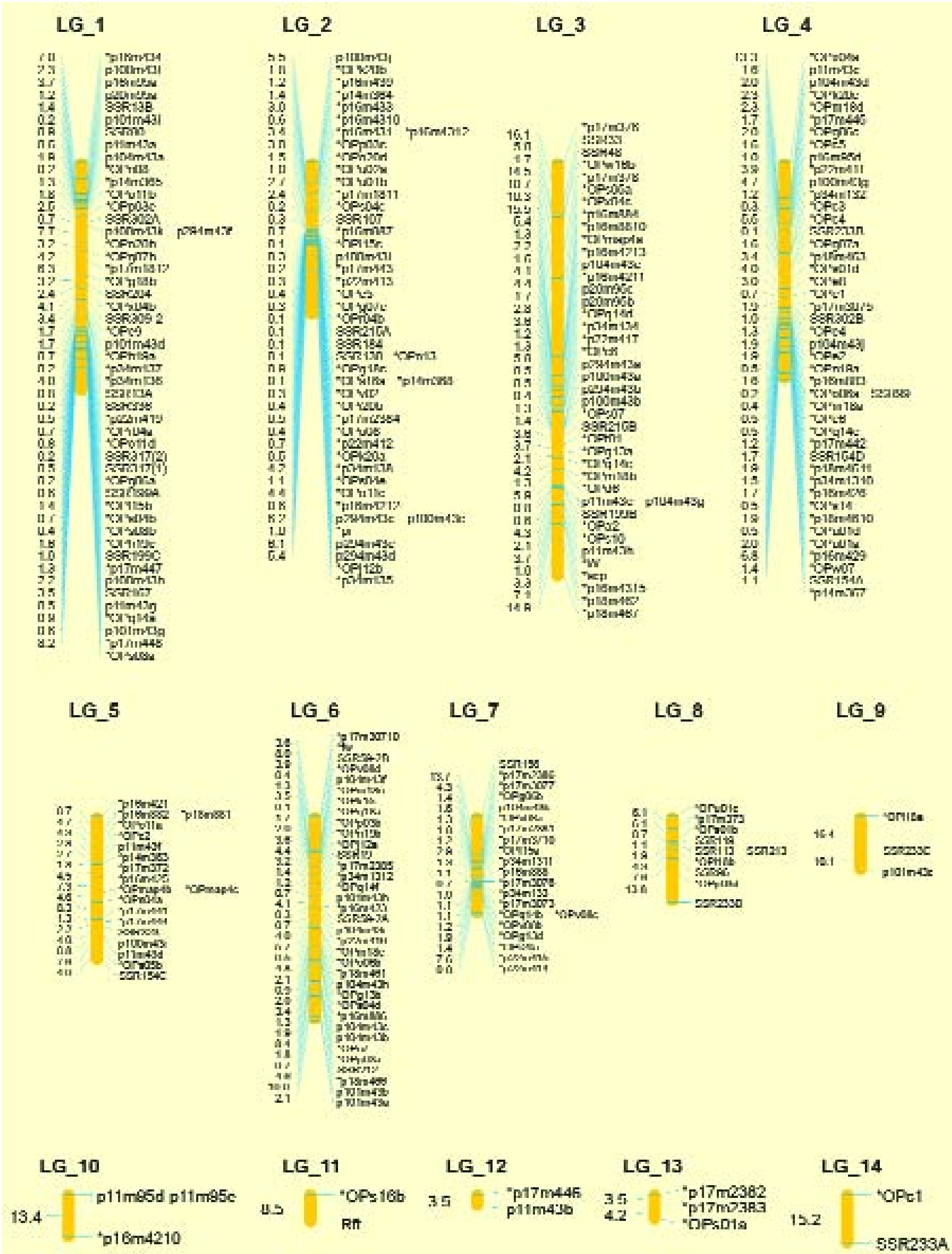


Fig. 14. A genetic linkage map of lentil (*Lens* sp.) based on micro-satellite, AFLP, RAPD and morphological markers. The map shows the position of micro-satellites (denoted as SSR_), AFLPs (denoted as p_m_), RAPDs (OP_), and the morphological markers for seed color pattern (*Scp*), flower color (*W*), pod indehiscence (*Pi*), *Fusarium* wilt resistance (*Fw*), and radiation frost tolerance locus (Rft) distributed on 14 linkage groups, at LOD score ≥ 3. The marker names starting with an asterisk (*) are the markers mapped by other researchers. The values on the left side of the individual linkage groups represent cMs calculated using the Kosambi mapping function.

Breeding for *Ascochyta* blight resistance in chickpea

Chickpea is an important crop wordwide, providing dietary protein and fodder, and also improving soil fertility. Despite this, the area cropped with chickpea has not increased over the last two decades—mainly because of the risk of crop failure due to diseases such as *Ascochyta* blight and *Fusarium* wilt.

Ascochyta blight is the most destructive fungal leaf disease of chickpea, reported from as many as 33 countries. Epidemics have caused serious crop losses in Italy, Spain, Syria, north-western India, Pakistan, the USA, and Australia. Furthermore, ICARDA's screening work has shown that all the local landraces grown in the WANA region are highly susceptible.

Over the years, ICARDA has shown that great variability exists in the fungus. Different races occur in different places and the fungus also changes over time—probably due to its sexual form of reproduction. To combat this variability, ICARDA scientists combined different sources of resistance to develop new genetic stocks; and worked with NARS researchers to identify new high-yielding resistant lines.

These have either been released or are in the process of being released in many countries. In 2005, for example, one new variety (Rafat) was released in Kyrgyzstan, and two new lines (FLIP 97-530C and FLIP 97-503C) were released in Australia. All produce large seeds and are *Ascochyta* blight-resistant, and all were released for general cultivation.

Researchers are also pyramiding different genes for resistance or

Newly developed *Ascochyta* blight-resistant chickpea lines (left), compared with a local variety (right) killed by the blight at Tel Hadya, 2005.

Table 6. Reaction of newly developed chickpea lines to various diseases and environmental stresses, and their flowering, height, and 100-seed weight characteristics, at Tel Hadya, Syria, 2005.

Line	*Ascochyta* blight (scale of 1-9†)	*Fusarium* wilt (% of plants killed)	Cold tolerance (scale of 1-9†)	Drought tolerance (scale of 1-9†)	No. of days to flowering	100-seed weight (g)	Plant height (cm)
FLIP 03-138C	3	5	5	3	114	41	41
FLIP 03-17C	4	10	4	4	113	35	49
FLIP 03-80C	4	0	5	5	112	32	47
FLIP 03-84C	4	10	5	5	113	31	49
FLIP 03-88C	4	0	4	5	112	32	48
FLIP 03-96C	4	0	5	4	110	30	43
FLIP 03-97C	4	5	5	4	111	31	47
FLIP 03-110C	4	0	5	4	105	41	40
FLIP 03-111C	4	5	5	4	108	40	41
FLIP 03-113C	4	5	5	4	108	39	40
FLIP 03-115C	4	5	5	4	112	34	41
FLIP 03-117C	4	0	5	4	110	34	42
FLIP 03-123C	4	10	5	4	106	41	42
FLIP 03-124C	4	0	5	4	106	37	38
FLIP 03-144C	4	5	5	4	108	39	38

† 1= most tolerant, 9 = most susceptible.

tolerance to various biotic and abiotic stresses. As part of this work, researchers evaluated many bulked lines during 2005 at ICARDA's Tel Hadya station. They found a number that had combined resistance to *Ascochyta* blight, *Fusarium* wilt, cold, and drought (Table 6). These lines have already been shared with national programs both within and outside CWANA, in order to develop a new, more resistant generation of chickpea varieties.

Inserting drought resistance-related genes into chickpea and lentil

Yields of chickpea and lentil in developing countries have increased in the last decade, because of improved varieties and better crop management. Despite this progress, stresses such as cold and drought still limit yields. These limitations cannot be overcome by classical plant-breeding methods alone, because genetic variation in the cultivars and their wild relatives is limited. However, by using a process known as 'transformation', scientists can insert genes that control traits such as drought resistance into new varieties of the two crops.

Researchers at ICARDA and the University of Hannover, Germany, have now developed a transformation system for chickpea. ICARDA had earlier also obtained a license for a lentil transformation system. These systems are being used to insert drought resistance-related genes into chickpea and lentil.

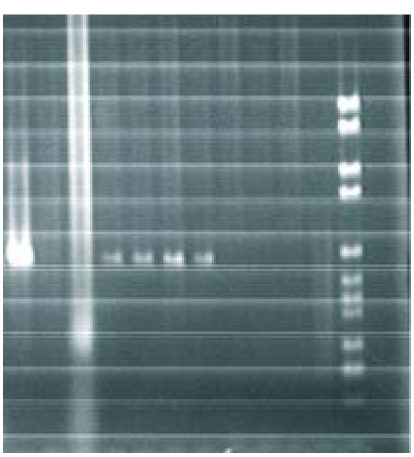


Fig. 16. PCR analyses of nptII marker gene in chickpea. From right to left: Lane 1—size marker; lanes 6-7—T0 transgenic plants; lanes 8-9—T1 transgenic plants; lane 10—control plant; lane 11—control plasmid; lane 12—construct plasmid with nptII.

To transfer these genes into chickpea, scientists conducted 23 experiments in containment facilities using the chickpea line ILC482, and either Kanamycin or G418 as a selection medium. DNA was actually transferred by inoculating seedlings with an *Agrobacterium* species capable of passing on its genetic material.

Until recently researchers relied on the selection medium to induce rooting. However, success rates were low and only a few explants

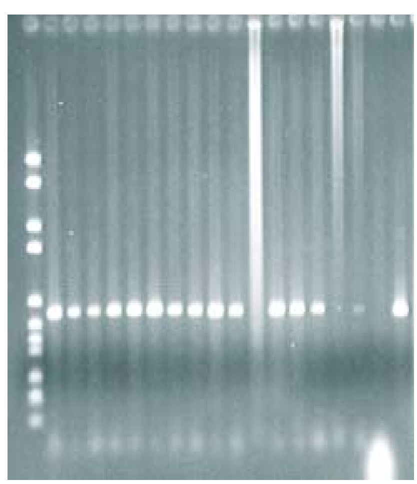
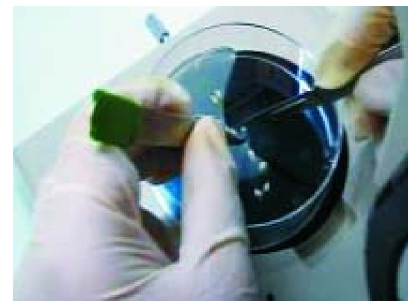


Fig. 17. PCR analyses of nptII marker gene in lentil. From left to right: Lane 1—size marker; lanes 2-15—T0 transgenic plants; lane 16—control plant; lanes 17-18—control plasmid; lane 19—construct plasmid.



Chickpea embryo tissue is cut at the apex and root tip and inoculated with a suspension of *Agrobacterium tumefaciens*, during a process developed by ICARDA and the University of Hannover, Germany. This introduces a gene for drought resistance.

produced roots. To overcome this, researchers grafted explants onto rootstocks from 5-day-old seedlings. Polymerase chain reaction (PCR) analysis showed that some of the T1 plants were transgenic. PCR also confirmed segregation of the transgene in T2 transgenic plants (Fig. 16).

Scientists also conducted 12 transformation experiments on three lentil lines—IL5588, ILL5883, and ILC5582—using drought-related genes with Kanamycin and G418 as the selection medium.

Grafting, usually on water-agar medium, is still an essential process in rooting lentil. Scientists grafted 46 putative transgenic explants. Once rooted, the explants were transferred to soft agar medium to allow plantlet elongation. Of these, 33 survived and were transferred to pots. PCR analysis confirmed that 21 T0 plants were transgenic (approximately 1%). A number of T1 plants also carried the transgene (Fig. 17).

Mechanisms of resistance to chickpea leaf miner

Leaf miner (*Liriomyza cicerina*) causes yield losses of up to 30% in chickpea in the WANA region. Breeding pest-resistant cultivars is the cornerstone of ICARDA's integrated pest management strategy, so germplasm containing resistance needs to be found. ICARDA scientists have developed new screening techniques and identified several sources of resistance. Two highly resistant lines (ILC 5901 and ILC 3800) have now been used to develop more than 200 advanced breeding lines (F_6) with good levels of resistance.

To understand why ILC 5901 and ILC 3800 were resistant to leaf miner, researchers also studied three types of pest resistance in the two lines – tolerance, antibiosis and antixenosis. All three mechanisms seemed to play a role, although the oxalic acid content of leaves was the main factor. Leaf oxalic acid content was significantly higher in the two resistant genotypes, than in a susceptible one (Fig. 15). This means chickpea breeders can use the oxalic acid content of leaves as a selection criterion for leaf miner resistance.

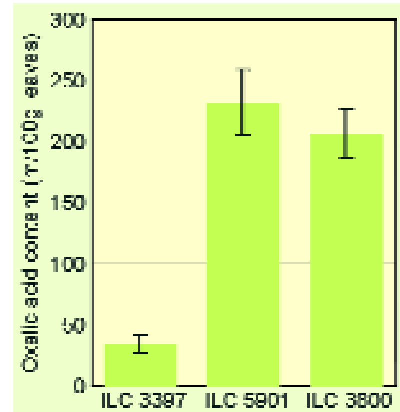


Fig. 15. Leaf oxalic acid content is significantly higher in two resistant chickpea genotypes (ILC 5901 and ILC 3800) than in a susceptible genotype (ILC 3397). ICARDA will therefore select for high leaf oxalic acid content when breeding for leaf miner resistance.

New faba bean with multiple resistance

Faba bean (*Vicia faba*) is a major source of protein for people living in developing countries in WANA, the Nile Valley region, China, and Latin America. It is also used as an animal feed and as a break crop in cereal rotation systems to sustain soil fertility. The main causes of low and unpredictable yields are two fungal diseases — chocolate spot (*Botrytis fabae*) and *Ascochyta* blight (*Ascochyta fabae*)—and the parasitic weed broomrape (*Orobanche crenata*).

Breeding for combined resistance

ICARDA has recently developed lines resistant to all three of these stresses. To do this, researchers first used single crosses to develop two improved faba bean populations. The first was created by crossing 14 types of chocolate spot-resistant germplasm identified by ICARDA with locally adapted varieties and lines from Turkey (ERESEN-87), Ethiopia (CS 20 DK), Egypt (Rebaya 40), Iraq (VF 123) and Sudan (STW). The second was created by crossing two chocolate spot-resistant accessions (BPL 1179 and L 82003-1) with four types of *Ascochyta* blight-resistant germplasm.

These crosses were made in plastic houses at Tel Hadya, Syria, during the 1996/97 growing season. In the following season, F_1 plants were raised in screen houses, then advanced to produce an F_2 population. These plants were allowed to cross randomly, through insect pollination in the field. Between 1999 and 2003, segregating populations (F_2 to F_6) were planted and evaluated at ICARDA's research sites at Lattakia and Tel Hadya in Syria.

Multi-site evaluation

At Lattakia, chocolate spot resistance was evaluated in screen houses after artificially inoculating plants with a spore suspension (100,000 spores/ml). At Tel Hadya, *Ascochyta* blight resistance was evaluated in the field. In both cases, a 1-9 disease scale was used (where 1 = healthy and 9 = killed by disease)

Chocolate spot is a very serious fungal disease in faba bean, and can cause complete crop failure.

Table 7. Average disease scores for new faba bean entries exposed to chocolate spot at Lattakia, and *Ascochyta* blight at Tel Hadya (2002/03 season) and the average *Orobanche* infestation rate (%) at Tel Hadya (2004/05 season), Syria.

Entry/check name	Average disease score†		Average infestation (%)
	Chocolate spot	*Ascochyta* blight	*Orobanche*
Sel. / 1552 / 2003	2	5	7
Sel. /1589 / 2003	2	4	0
Sel. /1590 / 2003	2	4	0
Sel. /1591 / 2003	2	5	0
Sel. /1593 / 2003	2	5	0
Sel. /1594 / 2003	2	5	0
Sel. /1597 / 2003	2	5	0
Sel. / 1598/ 2003	2	4	0
Sel. /1605 / 2003- 1	2	5	0
Sel. /1606 / 2003- 2	2	5	13
Mean (all entries)	2	4.7	2
Blight-resistant check (Ascot)		5.7	
Blight-susceptible check (Giza 4)		7.3	
Chocolate spot-resistant check (Icarus)	2		
Chocolate spot-susceptible check (Rebaya 40)	5.7		
Orobanche-susceptible check (ILB 1814)			100

†Disease score: 1 = healthy; 9 = killed by disease.

and superior plants were identified following pedigree selection.

Susceptible checks were used for comparison. Researchers identified 71 F_6 lines with a low disease rating for chocolate spot and 36 F_6 lines with a low disease rating for *Ascochyta* blight. Importantly, 24 lines showed combined resistance to both diseases.

Seeds of these dual-resistance lines (F_7) were multiplied in screen houses at Tel Hadya during the 2003/04 season. The following season, they were evaluated under a heavy natural infestation of *Orobanche* in a sick plot, along with a susceptible local check. By counting the number of *Orobanche* spikes per plant, researchers were able to estimate the infestation rate.

In this way, researchers identified 10 F_8 lines which were either free of *Orobanche* or showed a very low infestation rate (Table 7). The seed of these 10 lines, resistant to *Orobanche*, *Ascochyta* blight, and chocolate spot, will be multiplied next season and shared with NARS for further evaluation.

New efforts to control *Orobanche* in legumes

Broomrapes (*Orobanche* spp.) are widespread parasitic weeds which seriously limit the production of many leguminous crops in warm temperate and semi-arid areas. Faba bean, for example, is badly affected by *Orobanche*, particularly in the Mediterranean region. One species, *Orobanche crenata*, has been reported in 70-90% of faba bean fields in Morocco, and is devastating food legumes as it spreads throughout North Africa and parts of East Africa. Overall losses are rising—from an average of 18% in Morocco in 1984 to 30% in 2001. In certain areas of Sudan and Ethiopia, where *Orobanche* has only recently appeared, losses are as high as 75-100%.

Options for *Orobanche* control

ICARDA has tested several control options in different countries. Host-plant resistance and chemical control using new imidazoline herbicides, have both proved promising, as has delayed planting and the use of *Phytomyza orobanchia*, a natural enemy. Unfortunately, none of these techniques control the parasite adequately when used alone.

Controlling *Orobanche* will therefore require an integrated approach using complementary techniques and participatory training. This will help farmers understand how the parasite develops and spreads, what control options are available, and when they should be used.

Farmer field schools

FAO, ICARDA and seven countries (Algeria, Egypt, Ethiopia, Morocco, Tunisia, Sudan, and

Syria) have launched an intensive program to train legume growers and extension workers to manage *Orobanche*. This technical cooperation program (TCP) began in October 2004 and will continue for two cropping seasons. Three to five farmer field schools (FFS) have been set up in each country by national programs, with support from ICARDA and FAO. The overall objectives of the program are to:

1. Improve the ability of technical field staff and farmers to manage *Orobanche*.
2. Establish a sustainable network that will (i) collect and disseminate information on new weed control alternatives, (ii) enhance public awareness of the problem, and (iii) prevent *Orobanche* spreading to unaffected areas.
3. Develop a long-term project that will use an integrated pest management (IPM) strategy to control *Orobanche* in leguminous crops. This will be funded by governments, donor agencies and/or development banks.

A farmer field school in Sudan.

The program's farmer field schools are off to a good start, and participating farmers are already making decisions and applying recommended control measures.

In Sudan, FFS and national campaigns are being used to increase people's awareness of the threat and to train farmers and extension agents in *Orobanche* control. Efforts are also underway to prevent *Orobanche* spreading, by developing internal and external quarantine procedures and better crop-management packages.

***Orobanche* can completely wipe out faba bean (above) and lentil fields.**

In Morocco, FFS have been established in the country's major faba bean areas. These are based around agricultural cooperatives containing 30-40 small-scale farmers, each owning 20 to 60 ha of land. The IPM package being taught involves a mixture of chemical control, crop rotation, and manual removal.

Glyphosate herbicide use has proved to be the most efficient component of the package. However, older farmers find glyphosate difficult to apply, because precise doses have to be used, sprayers have to be calibrated, and the application has to be carefully timed. Moroccan scientists and extension specialists have therefore focused on teaching younger farmers and farmers' teenage children how and when to use it. This has proved very successful, and young farmers who have been trained are now using their time and equipment to teach others. The results are obvious, as there is far less *Orobanche* in the fields of FFS participants than in those of non-participants—many of whom are facing almost total crop failure.

Glyphosate is also proving effective in Tunisia, where *Orobanche* attacks crops such as carrot and tomato, as well as faba bean. Here FFS have been training farmers to use glyphosate properly—until recently growers relied on removing the weed by hand. This greatly reduced yields, because crop plants were often removed as well. Tunisia's farmers are showing great interest in the FFS concept, and farmers, extension specialists, and researchers are now exchanging information and recognizing each other's experience and knowledge.

In Egypt, FFS in areas such as Fayoum have disseminated *Orobanche* control options more effectively than previous extension efforts did. They have also made farmers aware that there is a specific level of infestation below which it is not economically worthwhile to treat a crop (the 'economic threshold'). Field schools have also increased farmers' confidence in extension agents, making them more willing to seek advice regarding the proper and safe application of chemicals. The program also found that FFS were even more successful if they addressed other problems faced by farmers (e.g. health, education and socio-economic issues) as well as *Orobanche* control.

National research systems played a key role in the rapid establishment of FFS in the seven countries, partly by encouraging extension services to collaborate with field schools at the different pilot sites. The large drop in *Orobanche* infestation as a result of the FFS program underlines the importance of involving farmers in decision-making. It also shows that farmers can be successfully integrated into efforts to develop national *Orobanche* control programs.

Identifying viruses in cool-season legumes

Over the last 15 years, virologists at ICARDA and NARS scientists from 11 countries have conducted surveys to identify virus diseases affecting cool-season food legumes. These surveys were conducted in Egypt, Eritrea, Ethiopia, Iran, Jordan, Pakistan, Tunisia, Turkey, Sudan, Syria, and Yemen. They have collected over 80,000 samples and tested them for 14 viruses. Results show that the most damaging virus diseases are those that cause yellowing and stunting. These have caused almost complete crop failure in chickpea and faba bean in many parts of WANA.

At least six viruses produce the same symptoms (leaf-rolling, yellowing, and stunting) in infected cool-season legumes. *Bean leaf roll virus* (BLRV), for example, was for many years believed to cause chickpea stunt, but recent research has shown that it can be caused by a number of viruses: BLRV, *Beet western yellows virus*, *Soybean dwarf virus*, *Chickpea luteovirus*, *Faba bean necrotic yellows virus* (FBNYV), and *Chickpea chlorotic dwarf virus*. These viruses belong to three distinct families: Luteoviridae, Nanoviridae, and Geminiviridae. This means that although a legume genotype may be resistant to one or two viruses, it could be very susceptible to others.

To breed resistant legume genotypes, scientists need to identify the specific viruses that affect legumes in the area where the crops will be grown. Diagnostic tools to identify viruses and their variants, and surveys to monitor the incidence and distribution of viruses, are therefore essential.

New diagnostic tools

In 2005, an ICARDA virologist spent a short sabbatical working with Australian scientists at the Victorian Department of Primary Industries to develop diagnostic tools for identifying yellows viruses. The sabbatical was supported by the Grains Research and Development Corporation, Australia. The research team screened Nanovirus and Luteovirus isolates from 11 countries (Australia, China, Egypt, Ethiopia, Iran, Jordan, Libya, Pakistan, Syria, Tunisia, and Yemen). They used (i) serologically-based tissue-blot immunoassay (TBIA) techniques, and (ii) molecular-based polymerase chain reaction (PCR) analysis.

The study produced three major results. First, virus-specific PCR protocols were developed to detect the three known Nanoviruses of pulses (Fig. 18A). *Subterranean clover stunt virus* was identified as the causal agent in Australia, *Milk vetch dwarf virus* (MDV) in China, and FBNYV in WANA countries. Previously MDV had only been reported in Japan. Second, generic degenerate primers were designed to detect all known Nanoviruses and Luteoviruses. These are very useful survey tools as they detect a broad range of Luteoviruses affecting field crops (Fig. 18B).

Third, PCR protocols were developed, or adapted from published protocols, to detect specific variations in viruses.

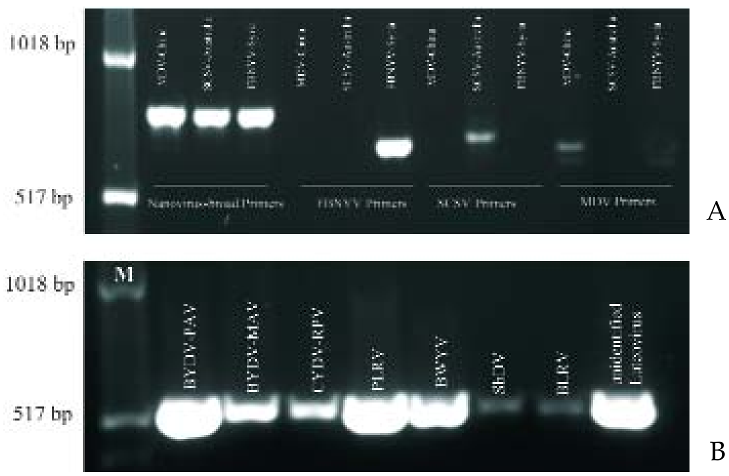


Fig. 18. PCR identification of Nanoviruses using broad and specific primers (A) and Luteoviruses using broad primers (B).

These diagnostic tools will help scientists identify the specific strains of yellows viruses that infect pulses. The tools will also have broader application. For examp,e, they will be useful to scientists in quarantine agencies and plant breeders screening lines for resistance to specific viruses.

First chickpea virus survey in Eritrea

Using the new diagnostic tools, an ICARDA virologist and researchers from the National Institute of Agricultural Research, Eritrea, conducted the country's first chickpea virus survey in November 2005. The survey, organized by ICARDA's Nile Valley and Red Sea Regional Program, identified various chickpea viruses, their incidence, and their relative importance in Eritrea's major production areas.

Over 6000 samples of chickpea were collected; 200 samples were selected at random from each of 31 farmers' fields—which were themselves chosen randomly. Researchers then determined the incidence of virus diseases by testing the samples against the antisera of nine legume viruses.

Tissue blot immunoassay and serological tests identified *Beet western yellows virus*, *Faba bean necrotic yellows virus* and *Chickpea chlorotic dwarf virus* in 5.6%, 4.1%, and 0.9% of samples, respectively. This was the first time these viruses had been identified in Eritrea.

Eritrean and ICARDA researchers carried out field observation and sample collection (left) and laboratory testing (right) simultaneously, as a part of the country's first legume virus survey.

Viruses infected over 6% of the samples from nearly two-thirds of the fields. Samples from three fields were found to have very high levels of infection—30%, 35% and 41%. These are likely to lead to significant losses for farmers.

Researchers also found that laboratory tests on samples were much more effective in assessing virus infection than field observations (Fig. 19). Field observers overestimated virus infection at low levels and underestimated it at high levels. For example, laboratory tests found only one field with an infection rate of less than 1%. Field observers, by contrast, judged that 29 fields had infection rates of less than 1%. In addition, field observers did not identify any fields with an infection rate greater than 21%. Laboratory tests, however, identified three such fields.

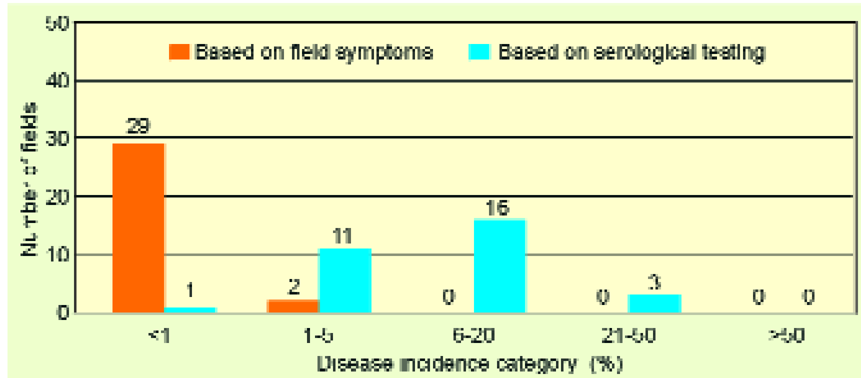


Fig. 19. Incidence of virus infection in chickpea crops recorded by field observers compared with the incidence determined by laboratory tests on samples collected at random during a survey conducted in Eritrea, November 2005.

The ICARDA virologist also trained Eritrean researchers in survey methods, symptoms of virus infection, and the use of tissue blot immunoassay to detect and identify viruses. The contacts established between Eritrean researchers and ICARDA during the survey will help support virology research in Eritrea.

Forage legume improvement for feed and sustainable production

Shortage of feed as a result of low rainfall is the major factor limiting livestock production in the dry areas—and affects the land and livelihoods of millions of resource-poor farmers. Forage legumes such as vetches (*Vicia* spp.) and chicklings (*Lathyrus* spp.) can withstand drought and require less water than other crops to produce large amounts of herbage, grain, and straw. In addition, *Rhizobium* bacteria in their root nodules fix nitrogen from the air and help to replenish soil nutrients.

These legumes are therefore an essential component of sustainable dryland farming systems, as well as a good source of feed for the rapidly growing livestock populations of the dry regions, especially in CWANA.

ICARDA's collection of *Vicia* species stands at 6010 accessions, and its collection of *Lathyrus* species at 3222 accessions. The Center uses this rich pool of genetic resources to develop new breeding populations and improved lines for distribution to NARS. These improved lines contain high levels of genetic diversity, allowing them to be grown under different environments and for a variety of end-uses such as direct grazing, hay-making, or grain and straw production.

The forage legumes international testing program disseminates improved genetic materials to NARS worldwide, through international trials. The elite forage legume lines produced are adapted either to a wide range of conditions, or to the specific conditions found in certain areas, and have useful quality traits. They are also resistant to biotic stresses such as pests and diseases and abiotic stresses such as drought. In 2005, ICARDA and NARS scientists continued collaborating to identify improved germplasm with specific or wide adaptation, and to target breeding efforts towards specific agro-ecological conditions and farming systems.

Improved vetches for China's alpine grasslands

Alpine grasslands account for 30% of China's total grassland area and are the major source of feed for the Yak and Tibetan sheep kept by millions of poor farmers in the region. They mainly occur on Qinghai-Tibet Plateau at altitudes above 2500 m, where annual temperatures average less than 5°C. The productivity of these grasslands has declined in recent years due to overgrazing.

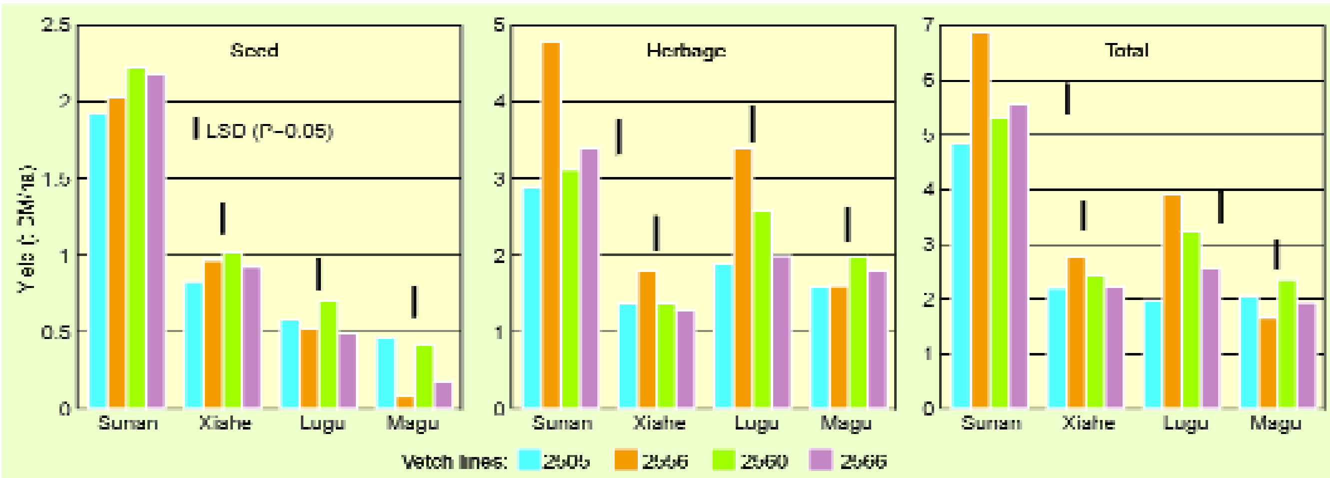


Fig. 20. Mean seed, herbage and total biological yield of improved lines of common vetch at four sites in Gansu Province, China.

To boost production, ICARDA's forage legume improvement project evaluated the grain and herbage dry matter (DM) yields of 10 improved lines of common vetch (*Vicia sativa*) and 10 improved lines of narbon vetch (*V. narbonensis*).

The first tests took place under alpine grassland conditions in Xiahe, Gansu Province during 1998 and 1999. Selection was conducted based on seedling vigor, cold tolerance, early maturity, and herbage and grain yields.

Nine common vetch lines and four narbon vetch lines were selected for their high grain, herbage, and total biological yields. Further selection identified the common vetch lines #2505, 2556, 2560 and 2566, and the narbon vetch line #2561 as having considerable potential for grain and herbage production.

The four best performing common vetch lines were then tested between 2001 and 2004 at four sites in Gansu Province. Lines #2560 and 2566 were found to be the highest yielding and showed adaptability to a range of conditions. They gave an average of 1.3 t/ha and 1.2 t/ha of grain and 2.5 t/ha and 2.4 t/ha of herbage, respectively, over all sites and years (Fig. 20).

Promising lines of common vetch grown under alpine grassland conditions, Gansu Province, China.

Importantly, though the sites used in China were in most respects similar to those in ICARDA's target regions where the lines were developed, temperatures were far lower (1.4-3.6°C). The common and narbon vetches selected therefore all contained cold-tolerance traits which can be exploited in cold regions.

Further studies are needed to integrate these promising lines into the crop–livestock farming systems used by smallholders in the region. For these improved lines to reach and benefit farmers, seed multiplication systems need to be developed in collaboration with local farming communities.

Vetches and chicklings for Brazil

Fundacep-Fecotrigo is a research foundation associated with 39 farming cooperatives (and 150,000

Promising selected lines of woolly-pod vetch in Rio Grande do Sul State, Brazil.

farmers) in Rio Grande do Sul State in the far south of Brazil. ICARDA first began to collaborate with Fundacep-Fecotrigo in 1999. The Center supplied improved forage vetch and chickling germplasm which was then evaluated under dryland conditions in the area. This work identified highly promising lines of four different types of vetch and chickling adapted to local conditions.

Two lines in particular gave high herbage and grain yields: *Vicia ervilia* sel# 2520 and *V. villosa* subspecies *dasycarpa* sel# 683 (variety Kouhak).

Both these lines are now in the final stages of testing in farmers' fields, and are candidates for seed multiplication and commercial release. They are likely to be promoted as dual-purpose crops, as they provide grain and straw to feed livestock, as well as green manure which can be used to recycle nutrients during crop rotations. As a result, these lines will play an important role in promoting sustainable agriculture and preventing soil erosion in the area.

Farmers profit from better vetches in Syria

In many dry regions, forage legumes such as vetches have great potential to contribute to sustainable development. However, this potential remains largely untapped as adoption has been limited. ICARDA's forage-legume improvement project is therefore paying particular attention to low-rainfall areas (250-350 mm per year). In such areas in Syria, forage legumes are not widely grown. Instead, farmers either grow cereals, usually barley, before letting the land lie fallow for a year or, increasingly, grow their cereal crops year after year without letting the soil recover.

To promote more sustainable farming systems, the program has developed improved lines and varieties adapted to these areas. These are now being tested on-farm in collaboration with the Aga Khan Foundation's Program for Rural Development, using a participatory approach. Collaboration began in 2003. The trials are being conducted in Salamieh, north-west Syria: a typical rainfed dryland farming area.

With technical backstopping from ICARDA, farmers at two locations managed and tested three already-released varieties of vetch: Baraka (common vetch), Kouhak (woolly-pod vetch), and

Table 8. Productivity and net returns (revenue) of improved forage vetch varieties tested in farmers' fields at Salamieh, northwest Syria (2004/05 growing season).

Variety	Tel Dora (rainfall 240 mm/year)								Qebelhat (rainfall 245 mm/year)							
	Yield (t/ha)		Price (SP/kg)‡		Income (SP/ha)			Net returns (SP/ha)†	Yield (t/ha)		Price (SP/kg)‡		Income (SP/ha)			Net returns (SP/ha)†
	Grain	Straw	Grain	Straw	Grain	Straw	Total		Grain	Straw	Grain	Straw	Grain	Straw	Total	
V. narbonensis var. Velox	1.8	1.5	14	6	25200	9000	34200	20120	1.5	2.3	15	7	22500	16100	38600	24520
V. sativa var. Baraka	1.4	1.6	14	7	19600	11200	30800	16720	1.4	2.7	15	7	21000	18900	39900	25820
V. dasycarpa var. Kouhak	1.0	1.1	14	7	14000	7700	21700	7620	1.3	2.7	15	7	19500	18900	38400	24320
Mixture barley + Kouhak	1.5	1.6	11	5	16500	8000	24500	10420	2.2	3.0	10	5	22000	15000	37000	22920

‡SP = Syrian Pounds. 1 SP = approximately US$0.02.
†Net returns (SP/ha) = Income – total production costs.
Note: Total production cost (SP/ha): fertilizer (1090) + seeds (1600) + cultivation (1500) + harvesting (6470) + threshing (3420) = 14,080.

Field day involving farmers, extensionists, and other stakeholders organized by ICARDA's forage-legume improvement project in Salamieh, Syria.

Velox (narbon vetch). These were used to interrupt continuous barley cropping. Kouhak was planted either as a pure stand or as a mixture with barley. At the end of the 2004/05 growing season, the Aga Khan Foundation conducted a preliminary impact assessment (Table 8). This showed that the net return (revenue) obtained from introducing improved vetch germplasm into the cropping system varied from 7,620 to 20,120 Syrian pounds (SP) at Tel Dora and from 22,920 to 25,820 SP at Qebelhat (Table 8).

New grass pea variety released in Central Asia

Field days involving farmers, extensionists, and other stakeholders were also organized as part of the project. As a result, more farmers were keen to join the scheme and try out the new technology in the 2005/06 season.

Grass pea (*Lathyrus sativus*) is a drought-tolerant crop that provides both animal feed and food for people. It can produce economically viable yields under adverse conditions, which makes it popular with subsistence farmers. It is widely grown in Africa and Asia and has the potential for expansion into marginal, low-rainfall areas in other regions as well.

Such dual-purpose food/feed crops are relatively new in Central Asia and the Caucasus (CAC), as they were rarely grown under the extensive cropping systems used in the former Soviet Union.

Importantly, the crop rotations used in the region usually include fallow periods, when large areas remain unsown. These fallows offer a great opportunity to produce forage legume crops such as grass pea.

Since 1998, therefore, ICARDA has been focusing on introducing improved forage crop germplasm into the CAC region. The aim is to achieve sustainable increases in crop and livestock production and diversify the cropping system, especially in areas where cropland is left fallow.

Large numbers of improved grass pea lines have already been introduced, and researchers from ICARDA and CAC countries have worked together to develop a selection program and evaluate and select new lines under rainfed conditions; and then produce adequate quantities of seed.

The aim is to ensure that the final products are palatable, competitive, high-yielding and fast-growing as seedlings. They also need to be cold- and drought-tolerant, and resistant to diseases and insect pests. Finally, and most importantly, they have to be almost free of the anti-nutritional factors which grass pea contains naturally and which are harmful to human health.

As a result of this program, a new variety of grass pea—Ali-Bar—was released in Kazakhstan in 2005, the first to be released in the CAC region. Ali-Bar was selected from ICARDA germplasm supplied to Kazakhstan and then tested over a four-year period. It yields 1.2 t/ha under rainfed conditions in areas with 250-300 mm rainfall.

In addition, the seeds contain consistently lower concentration (0.008%) of the neurotoxin ODAP, compared with grass pea land-races. The protein content is approximately 30%. This means the variety can be used as a multipurpose crop for direct grazing or for grain and straw production for winter feeding.

Scientists from ICARDA and Kazakhstan evaluating the newly released grass pea variety Ali-Bar which provides food for people and feed for animals.

Ali-Bar is derived from the ICARDA line sel #554, which is also being tested in Turkmenistan. It has already shown great promise there, and has been recommended for release.

International Crop Information System and International Nurseries Network

The International Crop Information System (ICIS) and International Nurseries Network made significant progress in 2005, boosted by support from the CGIAR's Generation Challenge Program. A new server installed during the year, for example, now holds all the databases for ICARDA's mandate crops.
On the Center's intranet, web-user interfaces were also launched for ICARDA's Chickpea and Barley Crop Information System and its varietal release database. In addition, the ICIS Genome Management System was updated with molecular data from Generation Challenge Program projects.

A prototype Genome Laboratory Information Management System (GLIMS) was also demonstrated at planning meetings in Wageningen, the Netherlands, in February. The first version was then presented in Vancouver, Canada, in August, and copies distributed to CIMMYT, IRRI, the University of Queensland, and the Semiarid Prairie Agricultural Research Centre (SPARC), Saskatchewan, Canada.

During the year, around 350 cooperating scientists on the Cereal and Legumes mailing list were sent information on the 2005/06 ICARDA international trial and nursery germplasm available.

Through the International Nurseries Network, ICARDA received 124 requests for 1945 sets of nursery/trial germplasm and dispatched 6.5 tons of seeds to 50 countries (Table 9).

Table 9. Distribution of germplasm through the International Nurseries Network, 2005.

	Crop	Sets	Yield trial	Observation nursery	Stress nursery	Segregated populations	Crossing block
Requested							
	Barley	505	128	182	120	34	39
	Spring bread wheat	196	144	51			
	Durum	178	76	77		25	
	Chickpea	317	116		169	32	
	Faba bean	101			82	18	
	Lentil	300	108		115	77	
	Forages	148	148				
	Winter wheat*	127	54	70			
	Facultative wheat*	80	65	15			
Total requested		1945	839	395	486	186	39
Sent							
	Barley	366	113	170	16	31	35
	Spring bread wheat	177	130	46			
	Durum	195	64	113		18	
	Chickpea	243	96		121	26	
	Faba bean	82			66	16	
	Lentil	234	94		92	48	
	Forages	133	132				
	Winter wheat*	21	11	10			
	Facultative wheat*	13	10	3			
Total sent		1461	650	342	295	139	35

* ICARDA/CIMMYT

Seed Health Laboratory

Germplasm exchange lies at the heart of ICARDA's work. However, importing and exporting plant material, particularly seed, can introduce and spread plant pests and diseases. ICARDA's germplasm-health safety measures are used to safeguard against these risks.

Testing the health of incoming and outgoing seed

In 2005, ICARDA's Seed Health Laboratory (SHL) tested over 30,000 accessions: an increase of 50% over the previous year. Seed of around 18,000 cereal accessions and 2500 food and feed legume accessions, was tested for seed-borne pathogens—fungi, bacteria, nematodes and parasitic weeds—before it was distributed around the world. The SHL also tested 616 accessions of faba bean and lentil seed for five key seed-borne viruses.

This testing ensured that all seeds dispatched were pest-free and documented in accordance with international quarantine regulations. During the year, ICARDA sent 222 germplasm shipments to 61 countries. These included 104 shipments to 47 countries of germplasm designated as 'international nurseries'.

ICARDA also received 29 seed shipments from 18 countries. The incoming seeds (6500 cereal accessions and 3500 food and feed legume accessions) were tested for seed-borne pathogens.

The most frequent infection found was that of common bunt of wheat (*Tilletia caries* and *T. foetida*). In some shipments, high levels of infection with dwarf bunt quarantine fungus (*Tilletia controversa*), up to 20%, were found in wheat accessions. *Ascochyta* blight was found in 4% of chickpea accessions. The seed gall nematode (*Anguina tritici*) was detected in 3% of wheat accessions.

All incoming untreated seeds were treated with a broad-spectrum fungicide. Only healthy seeds were planted in the post-quarantine fields and post-quarantine plastic houses.

Inspecting ICARDA's seed-multiplication fields

Scientists from the SHL also inspected 190 hectares of cereals and food and feed legumes. These areas are used to multiply seed for distribution through the international nurseries. In barley, the most frequent diseases found were barley stripe *(Pyrenophora graminea*) and loose smut (*Ustilago nuda*). Scald (*Rynchosporium secalis*), net blotch (*Helminthosporium teres*), and covered smut (*Ustilago horde*) infections were found in some accessions, while a few other accessions showed signs of black chaff bacterial disease (*Xanthomonas campestris* pv. *translucens*).

The most common infections in wheat were common bunt (*Tilletia caries* and *T. foetida*) and loose smut (*Ustilago tritici*). A small percentage of leguminous plants was found to be infected with *Ascochyta* spp. However, *Ascochyta fabae* caused more damage to faba bean than to other legumes. Some wilt infection (caused by *Fusarium* spp.) was detected in lentil.

During field inspection of the post-quarantine fields, scientists found *barley stripe mosaic* and *barley yellow mosaic viruses* in one barley accession. The accession was immediately destroyed.

Human resource development

During the year, two in-country seed health training courses were conducted in Afghanistan and Iran.

A one-month training course was organized at ICARDA headquarters for three individual participants (two Syrians and one Iraqi). In collaboration with Mosel University and Hawaii University, a senior scientist from the SHL supervised the Masters thesis of an Iraqi student from Mosel University.

Mega-Project 3

Improved Land Management to Combat Desertification and Increase Productivity in Dry Areas

Introduction

Desertification has been defined as land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities. The drylands cover some 41% of the global surface area and are home to around 2.1 billion people. More importantly, 72% of drylands are in developing countries and approximately half of the worlds' poor live in drylands. At a conservative estimate, 10-20% of land is already affected by desertification. This means that in terms of the number of people affected, desertification is larger than any other environmental problem.

Earlier definitions failed to emphasize that desertification is a development problem and not specifically an environmental problem. This is now clearly recognized by the United Nations Convention to Combat Desertification (UNCCD), which states that 'national action programs, designed to combat desertification, must be fully integrated into other national policies for sustainable development' and that 'combating desertification is really just part of a much broader objective: the sustainable development of countries affected by drought and desertification.'

Given the complexity of causal factors, an integrated approach with broad stakeholder participation is essential if the livelihoods – and security needs – of the people inhabiting drylands are to be improved without further degrading their environments. Technological, institutional, and policy options are required to prevent further land degradation and build viable livelihoods.

Mega-Project 3 aims to identify options for rehabilitating degraded land resources and, at the same time, improve and strengthen systems of land management to control degradation and sustain future production in order to contribute to sustainable livelihoods. Major elements of the Project include: the development and testing of an integrated approach to natural resources management; understanding the causes and driving forces of land degradation, including regional assessments of desertification; 'best-bet' technologies for the management of land, water and watersheds, vegetation and rangelands; policy and institutional research to create an enabling environment for combating desertification; and institutional strengthening and capacity building in integrated approaches to sustainable land management.

Combating desertification in marginal dryland areas

Syria's Khanasser Valley (80 km southeast of Aleppo) is a typical marginal dryland area prone to desertification. It receives little rainfall (220 mm per year on average) and even this is unpredictable, varying greatly from year to year. Poverty and degraded soils are widespread. Between 2001 and 2005, ICARDA used an integrated natural resources management (INRM) framework to address the Valley's complex and inter-related problems.

Funded by BMZ (Germany) and the Flemish Government, researchers gained a clear understanding of the major agro-ecological strengths, weaknesses, opportunities, and threats found in the Valley (Table 1). The different options for sustainable development identified through this work are likely to be applicable in similar marginal dryland areas throughout West Asia and North Africa.

An interactive multi-stakeholder process

Many different stakeholders were involved in the research. Through voluntary 'farmer interest groups' (FIGs), for example, farmers worked with researchers to analyze problems and select possible solutions, which they then tested and evaluated on-farm. Researchers also worked with Syria's Atomic Energy Commission and the country's Olive Research Department to study the area's natural resources and develop best-bet technologies. Other partners included Bonn University, which supported water resource assessment and water management work, and the Jabel Al-Hoss development project, which developed micro-credit systems.

This multi-stakeholder approach required extra consultation to achieve consensus and plan activities. It also ensured that only appropriate technologies were developed and that full use was made of local expertise and knowledge. The approach also increased partners' commitment to the project, by increasing their sense of ownership.

A toolbox of options

Even small differences in soil, slope, rainfall, assets, livelihood strategies, and community dynamics can cause a development option to fail. Partners therefore developed a range of technological, institutional and policy options (TIPOs) for use in the Valley and similar areas.

Khanasser Valley farmers have complex and integrated strategies to cope with the dry marginal environment.

Reducing rainfall-related risk

The project explored three main strategies for coping with low and variable rainfall: crop diversification, development of drought-resistant varieties, and better use of available water.

Diversifying into new crops such as olive, cumin, home-garden vegetables and wheat, ensures that all crops will not fail simultaneously. Researchers worked with local FIGs to assess produc-

Table 1. SWOT analysis of the Khanasser Valley, a typical marginal dry area.

Strengths
- Indigenous knowledge and local innovations
- Strong social networks and rich local culture
- Comparative advantage for small ruminant production
- Salt lake with rich bird biodiversity
- Relatively unpolluted environment
- Reasonable mobility and accessible markets
- Improved basic services (electricity, roads, mobile-phone network)

Weaknesses
- Cash-flow problems (resulting in lack of long-term investment)
- Poor nutritional status of children
- Limited experience with non-traditional farming enterprises
- Lack of adapted germplasm
- Decreasing productivity
- Degraded natural resource base (soil, groundwater, vegetation) + unsustainable management practices
- Land degradation is 'masked' by variations in rainfall
- Poor extension services and limited research

Opportunities
- Investing off-farm income in productive resources
- Better education levels and expertise
- Increased awareness of the risks of resource degradation
- Cooperatives
- Improved market information via mobile phones and other media
- Out-migration and off-farm opportunities
- Sheep fattening
- Potential to improve the traditional barley system
- Improved germplasm
- Diversification for cash and subsistence purposes
- Agro-, eco- and cultural tourism
- Runoff water harvesting and efficient small-scale irrigation systems
- Soil fertility improvement
- Rangeland rehabilitation and medicinal plant collection
- Better government services and a greater focus on poverty alleviation and environmental services in marginal areas

Threats
- Average age of working population increasing, and greater numbers of men working outside the Valley
- Weakening of social networks
- Neglect of traditional 'beehive' houses
- Increased population pressure and land holdings that are too small
- Depletion of groundwater resources
- Recurring droughts
- Further decline of soil fertility and groundwater levels
- Declining groundwater quality and salinization of irrigated fields
- Pollution from intensive sheep fattening and untreated village sewage
- Degradation and pollution of the fragile Jabul salt-lake ecosystem
- Unreliable export markets for sheep

Blue: livelihoods-related; red: enterprise-related, green: natural-resources-related; black: governance-related.

tion constraints for these new crops and find ways of overcoming them. These were then tested in farmers' fields. Researchers also organized extension days, to teach farmers how to prune olive trees and grow cumin.

Scientists have also worked closely with farmers to develop drought-resistant varieties. To date, over 200 lines of barley alone have been evaluated in a participatory breeding project run in three villages in the area. The superior varieties of barley identified are well adapted to the harsh conditions found in the Valley.

The project has also addressed the need to use available water resources more efficiently, by estimating groundwater reserves, calculating sustainable extraction rates, and testing the feasibility of drip irrigation. Researchers also found that harvesting runoff water in gently-sloping olive groves means that growers only have to irrigate their trees once in summer.

Building on comparative advantages

Syria's marginal dryland areas are well suited to rearing small ruminants—which gives producers there an advantage over those living elsewhere. Sheep fattening is expanding in the Valley as a result, and researchers are working with producers to test economical ways of producing feed on-farm.

Comparative advantages could also be exploited by producing mushrooms and medicinal plants. The Valley's rich history and unique biodiversity also mean that agro- and eco-tourism are income-earning options.

Participatory technology development combines local knowledge with scientific expertise.

Sustaining natural resources

Researchers also worked with farmers to find sustainable ways of rebuilding and maintaining the Valley's natural resource base. Options already identified include the application of phosphogypsum to soil, pre-summer tillage to reduce wind erosion, the construction of runoff harvesting structures, and better use of available manure.

Cropping vetch in rotation with barley, and planting *Atriplex* (saltbush) species as an alley crop in barley fields improved forage resources. However, for *Atriplex* alley-cropping to be attractive to farmers, subsidies would be needed.

Institutional options

Researchers also explored ways of using local organizations and arrangements to improve livelihoods. For example, support to dairy producers could potentially be channeled through *jabbans*—traditional cheese-makers who usually provide credit and sell cheese on the producer's behalf. The Jabel Al-Hoss project has recently introduced micro-credit facilities (*sanadiq*) to Khanasser. These allow poor households to take part in profitable enterprises that were previously beyond their reach.

Upscaling the lessons learned

Researchers are now working to ensure that the experience gained in Khanasser is applied elsewhere. Efforts to date include a policy briefing at Damascus and a multi-stakeholder workshop at ICARDA for research, development, and policy organizations. These have made decision-makers better aware of the solutions and opportunities that exist for dry marginal environments.

Surveys by ICARDA also showed that care needs to be taken when applying these lessons—as certain groups will benefit more from agricultural development than others. To avoid inequity, therefore, development efforts should also include investments to improve social services (e.g. health and family-planning centers, schools, and sanitation) and provide vocational training (to improve off-farm work opportunities). They must also take into account the effects that various development options have on women—as they contribute a significant amount of labor but have little decision-making power.

Soil erosion and conservation in olive orchards in hilly areas

In northwest Syria, olive cultivation has expanded over the last few decades into marginal areas, including fragile mountain regions with marl or chalky limestone soils. However, farmers are still using traditional land-husbandry techniques, which are not suited to olive growing on steeper slopes. This is resulting in tillage and water erosion, which is causing soil fertility to decline and is damaging olive productivity and economic growth.

As part of a plan to develop efficient and effective soil-conservation strategies, ICARDA has evaluated the long-term effects of growing olives on steep slopes. The Center also analyzed how farmers decided whether to apply soil-conservation measures, and assessed the soil-conservation advantages of natural vegetation strips on hillsides.

Long-term impact on land degradation

Researchers have evaluated the impacts that olive cultivation on steep slopes has had over a 50-70 year period. To do this, they compared the properties and profiles of soils in olive orchards with those of an adjacent reference forest.

The study showed that deforestation followed by cultivation causes a severe drop in soil quality. Soil depth had declined by at least 31% relative to the forest soil, while the soil organic matter content had dropped by 62%. Soil nutrient levels were also considerably lower: cultivated soils contained 62% less nitrogen, 48% less phosphorus, and 58% less potassium. The physical properties of orchard topsoils had also deteriorated significantly in comparison with those of forest soil: soil was more compacted (bulk density was greater) and more prone to water erosion (aggregate stability was lower).

The level of degradation was also strongly linked to topography. Most severe degradation was found on the steepest parts of the hillsides. In these areas, losses of soil organic matter and increases in bulk density were significantly greater than on the flat section at the top of the slope.

Overall, the study highlighted the severe level of historical degradation, and the need to stop further erosion by using simple alternative management practices. Only in this way will hillside olive production become sustainable.

Farmers' decision-making

Working with farmers in hilly olive groves in northwest Syria, ICARDA and its partners explored how farmers perceive land degradation. They also investigated what soil-conservation practices farmers used, and how they decided to apply them. In all, 43 villages were visited and 73 in-depth interviews conducted with farmers, extension workers, and other stakeholders in the area.

Based on these interviews, a holistic framework was constructed which describes farmers' decision-making with regard to soil conservation. This will be used to guide future development and research efforts.

The long-term impact of land use on soil was assessed by comparing undisturbed forest soils with orchard soils in northwest Syria.

Farmers' decision-making processes were found to be linked to the driving forces at the household level: the household's capital (financial, human, physical, social, and natural), and the household's social environment (including its social status). The study also took into account the three basic strategies that farmers used to cope with a fall in household resources triggered by land degradation.

These strategies were (1) non-farm activities (in the long or short term), (2) improved crop husbandry (short term), and/or (3) soil conservation (long term). Whether farmers adopted one or several strategies depended on their perceptions about the need for a particular strategy, how feasible it was, and how the strategy would affect their household capital.

Within the framework of these basic strategies, the decision making process was described in three dynamic stages: (1) motivation to farm, (2) motivation to tackle land degradation, and (3) motivation to apply a soil-conservation strategy. In our study we observed that the higher the motivation to farm, the higher the motivation to tackle land degradation and to apply a soil-conservation strategy.

Landowners who were more motivated to farm were more likely to observe, reflect on, and discuss the factors influencing agricultural production. As a result, they were more aware of land degradation. Farmers who were more motivated to tackle land degradation, observed, reflected on, and discussed soil-conservation strategies more. They were therefore more likely to experiment with soil-conservation innovations.

Controlling erosion with natural vegetation strips

To increase rainfall infiltration and control weeds, most farmers prefer to plow their olive orchards. However, this results in tillage erosion (the downhill movement of soil as a result of tillage). The extent of tillage erosion depends on factors such as soil type, the steepness of the slope, and the tool used to till the soil.

Tillage also increases water erosion, especially when farmers plow up and down the slope. Tillage erosion is now a very common problem in Afrin (north-west Syria), and a major threat to sustainable olive production. Simple cultivation systems to conserve the soil have therefore been tested.

In the natural vegetation strip system, farmers plow along the contour lines of the slope and leave a strip of natural vegetation between the trees untilled. This strip reduces tillage erosion and obstructs water flows—thus reducing water erosion.

To test the method, researchers at Tel Hadya measured the amount of tillage erosion caused by different methods of tillage. On a 12% slope, use of a natural vegetation strip and contour tillage reduced tillage erosion by 75% in comparison with a downhill tillage pass. In addition, the new technique also caused soil to accumulate on the uphill side of the vegetation strip, further reducing the risk of water erosion.

Formation of natural vegetation strips as a result of selective contour tillage in Khanasser Valley, Syria.

Simple and low-cost conservation measures, such as natural vegetation strips, enable more farmers to tackle land degradation. When the vegetation-strip system was discussed with farmers in Yakhour and Khaltan (north-west Syria), they concluded that it would be useful in fields where trees had been planted more or less along the contours of the slope. As a result of these discussions, one farmer began to test the system in his field during the following spring.

Outscaling integrated natural resources management

Based on increasing demand from national partners, ICARDA is working to mainstream its integrated natural resources management (INRM) framework and tools. Several hurdles have to be overcome to do this, as certain skills are needed to apply INRM and people often think that the method is complex. What is more, most partner research institutions have a single-discipline focus and lack the expertise needed for participatory and multi-stakeholder approaches.

As part of its INRM outscaling efforts, the Center has produced publications, and delivered seminars during regional meetings with NARS. The NARS staff have also been introduced to the concept during in-house training courses on natural resource management. Importantly, ICARDA is also providing practical training to its project partners through workshops and through the direct application of INRM during project implementation.

INRM training workshops

Through workshops, training on specific aspects of INRM was provided to senior staff from the Conservation Tillage and Mountain Agriculture projects in Morocco. Trainees were asked to decide which of the diagnostic tools, problem-solving tools, and process INRM tools were most appropriate to their needs. Brainstorming sessions were then used to help trainees learn how to apply those tools within their projects. The results of this group work were then fed directly into project-planning exercises.

Learning by doing

Iran's Karkheh River Basin Project falls under the CGIAR's Challenge Program for Water and Food. INRM has been built into this project from the start. As it progressed, therefore, staff were provided with hands-on training when necessary. In addition, 'reflection' points were used to assess the project's progress as part of a learning cycle. This approach encouraged collective learning and helped to identify any adjustments to the projects or further training that might be needed.

Lessons learned

Various lessons have been learned from the outscaling of INRM and these have already been fed into the design of future training programs. Key factors for success include ensuring that INRM workshops occur early in the project cycle, involve participants from different disciplines, and draw on actual examples of INRM in practice. There is also a need to ensure that project managers and facilitators are committed to providing follow-up after training, especially in the early stages of projects.

Bringing integrated natural resource management theory into practice in Iran.

Vegetation types and rangeland degradation in communities on the Syrian steppe

As part of its work to improve rangeland management, ICARDA recently assessed the impact that communities have on the natural resources they depend upon. Researchers studied rangeland degradation around 50 settlements in six provinces on the Syrian steppe: Aleppo, Hama, Homs, Damascus County, Raqqa, and Deir Ezzor.

A sample of rangeland species at a site in a dry area environment.

The study recorded vegetation types and indicators of rangeland health and degradation along three transects radiating from each of the 50 settlements. Positioned at 120° intervals in a circle around each settlement, these transects crossed both native rangeland and previously cultivated areas. The direction of the first transect from each settlement was selected by a village representative, who also advised researchers where each of the transects crossed the boundaries of community rangelands.

Researchers sampled 750 sites in the 50 communities, by choosing five sampling points on each transect. The first of these was 50 m from the settlement, and the last at the end of the transect on the community boundary. The other three were then equally spaced in between.

Soil erosion and rangeland degradation were assessed based on the presence of pedestals and terracettes, rills and gullies, and invasive plants, and on flow patterns, root exposure, litter cover, ground cover, wind erosion, and soil compaction.

To estimate how intensively rangelands were grazed, researchers also evaluated the quantity of animal droppings present and the degree of trampling by animals. All assessments were scored on a scale that ranged from 1 (none to very low) to 5 (very high).

Rangeland vegetation types were classified according to the domi-

Table 2. Dominant vegetation types and degradation levels at 750 sites in 50 Syrian steppe communities, sampled February–April 2005.

	No. of sites	% of sites
Vegetation type		
Previously cultivated	186	24.8
Noaea mucronata	136	18.1
Artemisia herba-alba	129	17.2
Anabasis syriaca	78	10.4
Native	51	6.8
Haloxylon articulatum	43	5.7
Haloxylon salicornicum	38	5.1
Barley	18	2.4
Salsola vermiculata	17	2.3
Wheat	16	2.1
Astragalus spinosus	12	1.6
Peganum harmala	9	1.2
Achillea conferta	7	0.9
Capparis spinosa	5	0.7
Tamarix penpindra	1	0.1
Native *Badia* species	4	0.5
Total	750	100
Level of degradation		
None to very low	30	4.0
Low	245	32.7
Moderate	331	44.1
High	136	18.1
Very high	8	1.1
Total	750	100

nant species in native rangeland, or the main land use. Previously cultivated land accounted for 25% of the rangeland in the study area (Table 2). *Noaea mucronata* dominated 18% of the study areas and *Artemisia herba-alba* 17%. *Anabasis syriaca*, a species that invades disturbed land, dominated 10% of the sample sites. Results showed that 20% of the sites were severely degraded (Table 2). Moderate degradation was found at 44% of the sites. The remaining 37% showed little or no degradation.

Mobility and feeding strategies of Syrian pastoralists

Throughout most of West Asia and North Africa sheep numbers are rising and overgrazing is causing rangeland to degrade. To help communities find the best ways of managing their range, ICARDA has been working to better understand rangeland management and pastoral systems in the region.

In 2005, ICARDA and Syria's Ministry of Agriculture surveyed six Syrian provinces: Aleppo, Hama, Homs, Raqqa, Deir Ezzor, and Damascus.

In these areas, researchers mapped *Bedouin* communities' rangeland, identified the main types of rangeland, and then characterized their vegetation. They also conducted socio-economic surveys, collecting information on livestock production and livestock-related movements from 313 typical households in 50 steppe communities.

Range use was characterized by asking herders how frequently they used rangeland sites over a six-year period (1999-2004) and how long they spent on a site each year. Researchers also studied the feeding strategies used and the intensification of production systems. Herders using more intensive systems were identified as those who gave their animals supplementary feed, and who were therefore less dependent on the range.

Defining categories of herders

The survey identified five types of community rangeland user (Table 3): 'opportunist', 'regular', 'less mobile', 'sedentary', and 'intensive'. Opportunist herders only use community rangeland in years when there is abundant forage, while regular herders use it every year for set periods and regularly move their herds between the steppe rangelands and the cropping zone.

Less mobile herders also use their community's rangeland site every year. However, they differed from the more mobile regular herders in that they had spent at least one whole year in their community (i.e. without moving to the cropping zone) during the six years covered by the study. Sedentary herders, on the other hand, never moved from their community rangeland site, even during dry years.

The intensive herders were drawn from all the above categories. What distinguished them was the fact that, to boost productivity, they had all provided their flocks with supplementary feed in April 2004 when grazing was at its best.

Factors determining herders' strategies

Researchers also developed a model to estimate how probable it was that a household would fall into one of the five herder categories identified. The model used household characteristics (age, composition, education, and assets) and community characteristics (such as population density

Movement of *Bedouin* communities in search of feed for their sheep and goats is guided by several factors which have a direct bearing on rangeland management. ICARDA is studying the herder categories and their strategies for moving their flocks.

and distance from markets, watering points and the cropping zone).

Results showed that households were more likely to practice opportunist herding if they lived far away from the cropping zone but owned some land within it. By contrast, households close to the cropping zone were more likely to be regular herders. Less mobile herders tended to come from communities with high densities of animals and small areas of land that had been cultivated before cropping was banned on Syria's rangelands in 1994. Households were more likely to be sedentary if the household head was relatively old or if the household contained a large number of women. They also tended to be situated relatively far from the cropping zone.

Sedentary households also tended to be close to towns and to have better access to watering points. This was also true of the intensive herders, whose flocks were usually larger than the average for their community.

The model also showed that households that depended on barley cultivation before the rangeland cropping ban now rely heavily on the stubble available for grazing in the cropping zone. Overall, it was clear that the various herding strategies used were not a matter of choice, but were to a great extent forced on herders as a result of where they lived and what resources were available.

The study showed clearly that great variation exists within Syria's rangeland communities. Efforts to improve rangeland management will therefore be carefully targeted to ensure that any new systems developed are appropriate for particular communities and the types of households they contain.

Table 3. Characteristics of the five categories of herders identified during a study of community-rangeland sites in Syria.

Number of households	Opportunistic 31	Regular 75	Less mobile 106	Sedentary 41	Intensive 60
Mobility pattern, 1999–2004					
Total no. of months on site in past 6 years	25.4*	32.2*	51.5*	72*	42.0
Coefficient of variation in length of residence	0.51*	0.06*	0.28*	0*	0.18
No. of months on site in 1999 (low-rainfall year)	2.8*	4.3*	6.7	12*	5.1*
No. of months on site in 2004 (medium-rainfall year)	7.8	5.9	9.8*	12*	8.9
Total no. of moves in past 6 years	4.0*	11.7*	6.3	0*	7.5
Feeding strategies, 2004					
Concentrate use (% of herders)	46.8	33.8*	44.7	49.5*	49.8*
Crop residue use (% of herders)	16.9*	46.8*	22.5*	18.1*	27.4
Grazing on community rangeland (% of herders)	36.3*	19.4*	32.8*	32.4	22.8*
Productivity indicators, 2004					
Productivity index†	0.46	0.43*	0.48	0.48	0.50
Total production cost per ewe (SP)‡	2,142	2,155	1,834	1,623	2,412*
% of lambs fattened	33	42	40	22*	54*
Community-level mobility and fattening patterns, 1999-2004					
Average 'herder presence'§ 1999-2004	0.40*	0.43*	0.56*	0.59*	0.53
Variation in 'herder presence' 1999-2004 (coefficient of variation)	0.66*	0.41	0.42	0.37	0.39
'Herder presence' in 1999 (low-rainfall year)	0.28*	0.30*	0.40	0.49**	0.36
'Herder presence' in 2004 (medium-rainfall year)	0.52*	0.52*	0.68*	0.65	0.62
% of residents fattening their lambs	63.4	77.6	65.5	61.3	86.1*

*,** Significantly different from all other means at the 5% and 1% probability level, respectively.

† Indicator of productivity obtained through a factor analysis from four variables (mortality rate, lambing rate, milk production per ewe and per year, percentage of ewes that gave birth to twins).

‡ SP = Syrian pound; in 2005, 1US$ = 50 SP.

§ Indicator of use of community rangeland, calculated as (No. of households with sheep x months spent on community-rangeland site per year)/(total no. of households who use community-rangeland site x 12)

Sheep behavior and preferences for rangeland shrubs

Rangeland rehabilitation in CWANA often involves planting drought-tolerant shrubs to supplement native vegetation and provide grazing for sheep and goats. In the summer of 2005, ICARDA researchers at Tel Hadya, Syria, assessed this practice by studying sheep behavior and grazing preferences on a native rangeland area planted with rows of drought-tolerant shrubs six years before.

Every day, for nine weeks—from the end of June to the end of August 2005—90 female sheep were allowed to graze the rangeland area. Researchers observed the behavior of five marked sheep for 10 minutes each week. As well as recording the number of seconds they spent displaying different behaviors, such as walking, drinking, sleeping, and browsing, the researchers also recorded the species of shrubs grazed.

Around 48 native species were found in the study area, including wild oats, clovers, herbs, and grasses. The 19 non-native species of shrubs planted in the area consisted mainly of saltbush (*Atriplex*) with some *Salsola, Haloxylon*, *Kochia*, medic (*Medicago*), and *Coluteal* species, as well as five legumes.

The sheep grazed the very dry, brown, and over-mature native plants and palatable leguminous species first. They only began to graze the non-leguminous shrubs after the fifth week, once most of the native plants had been eaten (Table 4). Even then, they spent more time walking than grazing these shrubs.

Rangelends support a diverse range of native species, but sheep and goats have their own preferences for grazing. This research is helping ICARDA identify the species preferred by small ruminants and use them to rehabilitate degraded rangelands.

Table 4. Sheep behavior (seconds spent on each activity), when given free access to a rangeland of native vegetation rehabilitated with non-native shrubs, over nine weeks at Tel Hadya, Syria.

Week	Grazing shrubs	Grazing native species	Grazing roots of native species (after digging)	Walking	Stopping	Drinking	Sleeping
1	65.2	495.0	0.0	25.2	2.2	12.4	0.0
2	33.2	438.4	0.0	103.4	10.0	8.8	6.2
3	13.8	498.6	0.0	85.4	1.0	1.2	0.0
4	23.6	445.8	0.0	128.8	0.0	1.8	0.0
5	178.0	279.2	9.6	105.6	15.6	12.0	0.0
6	108.0	326.4	23.2	128.8	3.2	10.4	0.0
7	117.8	278.0	36.6	158.0	7.4	2.2	0.0
8	9.2	306.6	140.6	141.0	2.6	0.0	0.0
9	17.2	49.2	63.8	289.2	175.8	4.8	0.0
Mean (over 9 weeks)	62.9	346.4	30.4	129.5	24.2	6.0	0.7
% of total observation time	10.5	57.7	5.1	21.6	4.0	1.0	0.1

Researchers also noted that once sheep had eaten all the native vegetation above ground, they preferred to dig for underground rhizomes, forbs, and grass stems rather than browse the abundant foliage on the shrubs. Once they began grazing the non-leguminous shrubs (after week 5), they mostly grazed *Salsola* species and a Spanish variety of *Atriplex halimus*, which is similar to the native saltbush.

Sheep showed a clear preference for native vegetation throughout the trial (Table 3), spending 60-97% of their time grazing native species and only 3-38% grazing shrubs. This means that native vegetation could be heavily grazed, and even eliminated, before sheep will resort to browsing saltbush. The intense grazing pressure placed on native vegetation as a result may explain why it is so sparse and degraded.

This means that projects that aim to rehabilitate rangelands by planting shrubs may have the opposite effect, causing the remaining native vegetation to degrade completely. In the worst-case scenario, the land could become completely barren once plantations of non-native shrubs eventually die. This could happen after a couple of decades, as the non-native shrubs have a life span of around 20 years and do not re-seed naturally.

In addition, rehabilitation projects often target the least-degraded areas of rangeland, which have adequate native shrub cover. This aggravates the situation.

Researchers found one case, for example, where *Atriplex* was planted in an excellent stand of native *Artemisia* because this was the only land available and the project managers needed to meet a quota. Such cases are common in Syria and Lebanon. Clearly, therefore, rangeland rehabilitation efforts must take account of the habits and preferences of grazing animals.

A new partnership for sustainable land management in Central Asia

A lack of agricultural inputs and market opportunities is forcing rural communities in Central Asia to over-exploit their natural resource base. As a result, both highland and lowland areas are degrading at an alarming rate. Deforestation is increasing, as is rangeland overgrazing—especially near villages. At the same time, soil and water quality are falling and crop yields are declining.

To address these threats, ICARDA is working with the Central Asian Countries Initiative for Land Management (CACILM) Task Force. This aims to implement the United Nations Convention to Combat Desertification in five Central Asian countries: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. CACILM is led by the Asian Development Bank (ADB) with support from agencies from Canada (CIDA), Germany (GTZ), and Switzerland (SDC), and the International Fund for Agricultural Development (IFAD).

By assessing the ecological, institutional, and economic aspects of land management, working groups in each of the Central Asian countries have already ana-

A new consortium in Central Asia is helping communities move towards sustainable use of natural resources.

lyzed the root causes of land degradation. This work has helped them identify priorities for action as well as a suite of sustainable land-management options. It also clarified various research needs. In all countries, it was concluded that research is needed to develop better agronomic and soil and water conservation practices, and to diversify crop and livestock production to boost incomes.

Germplasm collection will also be important, as researchers need to develop crop varieties that can tolerate drought, salinity, and extreme temperatures.

The working groups also called for research to improve water-use efficiency, water allocation, and rangeland, feed and livestock-management strategies. New policies and institutional options are also needed, as are better ways of managing forests, and rapid and inexpensive methods to assess and monitor land degradation.

To address these research needs, ICARDA has developed an appropriate research framework, which is now being discussed by CACILM partners. This will be used to develop and apply innovative and sustainable land-management practices and to integrate sustainable land management into government development priorities and policies. The framework will also help the program's partners to strengthen human, technical, and institutional capacity, and encourage greater public and private sector investment in already-degraded areas, thus preventing further degradation.

Indigenous forage crops for the Arabian Peninsula

Large areas of the Arabian Peninsula suffer from some form of desertification. The primary cause is overgrazing. Since the 1960s, livestock production has increased sharply, thanks to better veterinary services and provision of subsidies that enable farmers to purchase processed feed and baled hay. In 1998 there were an estimated 24 million animals, mainly sheep, goats and camels. Overgrazing reduces the productivity of the ecosystem as well as the nutritional value and relative abundance of plant species. Rangelands do not provide sufficient forage, so farmers extract groundwater to produce irrigated forage – further exacerbating water shortages.

ICARDA's Arabian Peninsula Regional Program aims to address these problems by promoting indigenous forage species that can provide forage for livestock and simultaneously rehabilitate degraded rangelands. Collection missions were carried out in different countries in the Peninsula. Several of the species collected have high water-use efficiency and great potential value as forage crops.

More and more farmers in UAE's Central Agricultural Region want to grow the new forage Buffel grass or Leybid (*Cenchrus ciliaris*). To cope with the increasing demand, ICARDA and the Ministry of Agriculture are using

Overstocking can exhaust vegetation cover on rangelands (left), but stricter control of grazing allowed pasture to recover rapidly in Al Jouf, Saudi Arabia (right).

Seed production fields at Dhaid Research Station, UAE, December 2005.

direct seeding, rather than planting seedlings. This method requires frequent irrigation and good weed/pest control. However, once established, Leybid can be harvested ten times per year, with an average dry matter yield of up to 20 t/ha.

The water-use efficiency of Leybid (quantity of water to produce 1 kg of dry matter) is 25 to 50% higher than Rhodes grass, a popularly used forage. The Dhaid Research Station has intensified seed production of Leybid and Da'e (*Lasiurus scindicus*); around 1.7 tons were produced in the past two seasons. The station's seed unit – jointly established in 2002 by ICARDA and the UAE Ministry – is also producing several other indigenous forages.

Similarly, in Saudi Arabia, ICARDA and the Ministry of Agriculture are establishing a seed technology unit to enhance seed production of native range plants, particularly shrubs. A seed scarifier and a seed cleaner will soon be installed, and additional equipment for the unit is being procured.

In Oman, varieties of spineless cactus introduced from Tunisia in 2004, are now well established at the Rumais Research Station; and will be distributed to other countries in the Peninsula. Leybid seed is being multiplied at the Livestock Research Center in Rumais, for an ongoing program to re-seed degraded rangelands. Sixteen sites (0.25 ha each) were seeded in December 2004, and are being monitored.

Rangeland in the highlands of Yemen is being rehabilitated in collaboration with the Wallan community.

In Yemen, rangeland rehabilitation efforts in the Wallan community are continuing, using a combination of indigenous shrubs and water harvesting techniques. Pasture productivity has increased from 0.5 t/ha in 2003 to 1.8 t/ha in 2005.

Mega-Project 4

Improvement, Intensification and Diversification of Sustainable Crop and Livestock Production Systems in Dry Areas

Introduction

Within developing-country dry areas, the majority of the rural population is involved in the agricultural sector. Both crops and livestock contribute significantly to the livelihoods of the poor. Mega-Project 4 focuses on enhancing income generating options for the rural poor from crops and livestock, especially small ruminants; improving, intensifying and diversifying agricultural production systems; increasing and diversifying outputs; improving the safety, quality and marketability of the produce; and adding value through agri-processing of primary products, while sustaining the resource base. It aims to contribute to the development of productive and sustainable systems that enhance nutrition and livelihoods and generate opportunities for rural agri-business development and increased employment.

Medicinal and aromatic plants for alternative livelihoods in Afghanistan

At least 65 of the medicinal and aromatic plant species that grow in Afghanistan could be exploited commercially. These species are therefore the focus of three of the 11 projects managed by ICARDA under the Research in Alternative Livelihoods Fund (RALF), which is supported by the UK Department for International Development (DFID). These projects aim to raise incomes and create jobs by helping collectors, farmers, and traders make greater use of the country's plant resources.

Sources of natural active ingredients for food, pharmaceuticals, and cosmetics

In 2005, a Novib-Oxfam Netherlands project focused on six medicinal species: liquorice (*Glycyrrhiza glabra*), cumin (*Cuminum cymium*), Devil's dung or 'hing' (*Ferula asa-foetida*), caraway (*Carum carvi*), wormseed (*Artemisia cina*), and Indian jujube (*Ziziphus jujuba*).

The project is managed by ProFound, the Netherlands, and is being implemented by the Ministry of Agriculture, Animal Husbandry and Food (MAAHF), the Faculty of Pharmacy of the University of Kabul, and the United Nations Development Fund for Women (UNIFEM). Three NGOs are also key implementing partners (Table 1).

In the nine provinces covered, the project partners are working with communities, collectors, farmers, and traders to find the best ways to collect, grow, process, and market these species. Efforts aim to add value, and include the development of harvest and post-harvest technologies, and work to better understand the plants' properties—by analyzing and identifying bioactive compounds and other substances of interest. Researchers are also mapping the distribution of these species, and developing quality standards to ensure that products can be exported. This work is complemented by the project's efforts to build policy and legal frameworks.

Cumin is not only a medicinal crop, but is also widely used in food preparations.

Table 1. Plant species containing valuable natural compounds that are being targeted by the Novib-Oxfam/RALF project in nine provinces of Afghanistan (frequency of occurrence of species: x = low, xx = medium, xxx = high).

Province	Implementing NGO†				Products		
		Artemisia	Caraway	Cumin	Hing	Liquorice	Jujube
Khost	TLO	xx	xx	xx	x	x	
Paktia	TLO	xx	x	x	x		
Badakshan	AKF	xxx	xxx	xx		xx	
Baghlan	AKF	xxx	xx	x	xxx	xxx	
Bamyan	AKF	xxx	x	x	x	x	
Herat	CHA	xxx	xx		xxx	xxx	xx
Ghor	CHA	xxx	xx	x	xxx	xxx	x
Farah	CHA	xxx		x	xx	xxx	
Faryab	CHA	xxx	xx	x	xxx	xxx	xx

†TLO = Tribal Liaison Office; AKF = Aga Khan Foundation; CHA = Coordination of Humanitarian Assistance.

Growing and marketing saffron

Saffron (*Crocus sativus*) is a high-value crop that is mainly harvested and processed by trained women and girls. These groups benefit from the income-earning opportunities the crop provides, as around 270 days of labor are needed per hectare. The sustainable production, processing, and marketing of saffron is the aim of another RALF project. Led by the Danish Committee for Aid to Afghan Refugees (DACAAR), the project involves three other partners: Washington State University, MAAHF-Herat, and Herat University's Faculty of Agriculture.

Saffron is a high-value crop mainly harvested and processed by women and girls in Karokh, Herat Province.

Since its introduction in 1991, saffron-growing has spread rapidly in Afghanistan—to 21 districts in seven provinces. In Pushtun Zarghun district in Herat province, where DACAAR introduced saffron-growing in 1998, 119 farmers are now involved in saffron production. To help them, the project has established a Saffron Association, which already has 91 members, and a seed bank which is providing saffron bulbs (corms).

Around 30 ha of saffron are now being cultivated each year in Herat province. Many farmers want to start growing saffron, which has led to a great demand for corms. Established saffron farmers are earning extra income by harvesting and selling the excess saffron bulbs they produce.

The project is now focusing on improving production and identifying new market opportunities. As quality is the key to obtaining higher prices on international markets, growers and researchers have together worked out ways to meet ISO quality standards governing moisture content, flavor, and color. These include:

- Picking flowers early in the morning, before they wilt.
- Carefully separating stigmas from flowers and styles.
- Careful drying—to ensure that the final product only has a 12% moisture content. Too much moisture causes spoilage and mold, while too little leads to brittleness and loss of weight.
- The use of proper packaging—to maintain moisture levels and attract consumers.

H.E. Mohammed Sharif (second from left), Deputy Minister of Agriculture, Afghanistan, along with Dr Randhir Singh (fourth from left) of Relief International, and senior scientists from ICARDA Kabul Office, at a farmer's mint field in Jalalabad, Afghanistan.

Another RALF project, led by Catholic Relief Services, is studying agronomic issues using multiyear on-farm trials in Herat. Results have shown that larger saffron corms produce significantly more flowers and corms, and that saffron grows best when bulbs are planted at a depth of 15-20 cm at a spacing of 15 x 20 cm. In some areas, such as Pashtun Zarghun, it is best to plant saffron in raised beds to ensure good drainage.

The project has also shown growers that regularly digging up and replanting corms reduces the threat posed by pests and diseases. This also ensures that the best new corms are planted at the optimum depth—without regular replanting, bulbs eventually end up close to the surface because the new corms form above the older ones. Replanting also allows producers to gather surplus corms. Good quality ones can then be sold, while poor quality (small) corms can be used as animal feed.

Mint cultivation as a viable alternative livelihood

Scientists from ICARDA and Nangarhar University are working in Helmand, Kunduz, and Nangarhar provinces to help farmers produce mint (*Mentha* spp.) commercially on a large scale, as a viable alternative to growing opium poppies. They have already set up research/ demonstration plots, trained farmers by organizing field days, and founded mint producers' associations.

Project staff have also helped farmers to set up plastic houses so that they can produce mint using protected-agriculture technology. This means they can sell the crop in winter when prices are very high. The team has also introduced mint growers to the dry-mint trade, teaching them how to dry, package, and store the mint when prices are very low. This mint can also be sold for a high price in winter.

Four mint-water extraction plants have been imported from Iran and are being installed in the target provinces. The mint producers' associations will use these plants to manufacture mint-water, which they will market as a herbal remedy for common stomach problems. The project is also bringing in improved germplasm and new technologies for extracting mint water and distilling mint oil.

So far, 15 improved varieties have been imported and established in the project's mint-germplasm collection center. Some of the rarer varieties were multiplied using micro-propagation techniques. Nine local mint varieties were also collected and identified. Researchers studied their oil content and the chemical composition of their oil using high-performance liquid chromatography (HPLC) techniques.

The sale of bottled mint water, which is used as a remedy for common stomach problems, is rising in Afghanistan.

New links developed

Through the RALF projects' capacity-building activities, links have been built with Afghan universities and MAAHF's provincial research and extension teams. Several medicinal crop experts were also brought together for the Symposium on Medicinal Plants (held at MAAHF-Kabul in November 2005) and a week of activities in Kabul and Herat. The projects have also forged links with the Qarshi Herb Research Centre, Pakistan, and the Forestry and Rangeland Institute and Khorasan Research Centre for Technology Development, Iran.

Potential for oilseed crops in northern Afghanistan

Afghanistan imports more than 90% (over 180,000 tons) of the vegetable oil it consumes each year. However, the country's farmers cannot take advantage of this huge potential market because they lack access to suitable oilseed crop varieties and good quality seed. Overcoming these obstacles could help farmers abandon poppy farming in favor of oilseed cash crops.

Researchers from the Joint Development Associates International (JDA), the Aga Khan Foundation, CIMMYT, and Cornell University are therefore testing oilseed crops in northern Afghanistan. This three-year research project is managed by ICARDA and funded by the UK Department for International Development.

Researchers have evaluated the performance of new oilseed crops as well as new varieties of the oilseed crops that some farmers are already growing. Crops tested include soybean, peanut, sunflower, maize, and sesame, both on-farm and at research stations.

Introducing soybean to Afghanistan

Soybean can be used to produce cooking oil and nutritious foods, as well as protein- and energy-rich feeds, which increase milk production in cows and speed up growth in poultry. Growing soybean also adds nitrogen to the soil, which is important as many Afghan farmers cannot afford to buy fertilizer.

Soybean is a new crop in Afghanistan. It does have considerable promise, however. In the short term, for example, Afghan producers could export soybean to Uzbekistan, where there is great demand from poultry farms. In the longer term, strong markets for cooking oil and livestock and poultry feed already exist within Afghanistan. Market research by the Aga Khan Foundation, for example, has shown that Afghan consumers prefer soybean oil but consider it expensive.

Trials in 2005 have helped researchers identify which soybean varieties are suited to northern Afghanistan, with some varieties yielding as much as 2.5 t/ha when planted following a wheat crop. The yield from soybean planted earlier in the season could be even higher. The next step is for researchers to select the best varieties from among those tested. Introduction of these varieties, coupled with suitable methods of cultivation, could encourage farmers to adopt soybean as a new cash crop. However, the yield potential under local farming practices is still unknown. Most importantly, planting needs to be mechanized in a simple, appropriate way, perhaps through the Chinese 2-wheel tractor, which JDA is testing. Planting soybeans by hand on a large enough area so that it is profitable involves too

In Afghanistan, soybean is a new crop with considerable promise.

much labor, thus reducing or eliminating their profit potential. In sum, while soybeans have many uses and could be of great benefit to Afghan farmers, more work is needed to determine their profit potential.

Assessing canola, safflower, sesame, and flax

The project is also assessing different varieties of canola and safflower. Canola grows well in northern Afghanistan when sown in the fall, and could grow well even in dry areas if sown in the late winter and early spring. It is a relatively easy crop to grow and thresh, and has a high content of good quality oil—up to 40% in some varieties.

Safflower is another promising oilseed crop. Being extremely drought-resistant it is well-adapted to dryland cropping. Where soil temperature and moisture conditions are favorable, the root system can penetrate as deep as 3 m. Safflower seed also has a high oil content—up to 41% in some varieties. Early results indicate that safflower can be grown successfully when planted as an early spring crop. However, even better results might be obtained through planting as a fall crop, thus maximizing the use of winter rains in dryland areas. Researchers will start testing safflower varieties for northern Afghanistan in 2006.

In dryland areas, sesame, another drought-resistant oilseed, is also sometimes planted after winter wheat. Sesame is the preferred oil for making *pulau*, the national rice and meat dish. Although sesame oil is the most expensive on the market, it tends to be in short supply. This means that sesame could be a profitable crop. In 2005, researchers evaluated the performance of 45 sesame accessions (from the United States Department of Agriculture) when grown after a wheat crop. In 2006, they will conduct further trials on those that performed well in 2005.

Canola has a high content of good quality oil and grows well in northern Afghanistan when sown in the fall.

Safflower is a drought-resistant crop with great potential in Afghanistan.

Researchers are also investigating the business opportunities and potential export markets for flax and sesame. Provided quality standards can be met, sesame and flax seed could be exported to North America. The simple mass selection will continue in 2006, with another round of selection on seed saved from 2005.

Capacity building

The project also aims to build the agricultural-research capacity of national institutions, such as the MAAHF, and the Balkh

University Faculty of Agriculture. Staff from these institutions have rarely had the opportunity to gain hands-on research experience or to work directly with farmers. Lecturers and students from Balkh University therefore took part in the testing of soybean, maize, canola, and flax. In 2005, they evaluated 20 soybean varieties. JDA and other RALF partners are exploring the potential for organic production and certification of flax and sesame to meet demand in Europe. Sesame is already exported to Turkey, so the market chain is already partially established. MAAHF staff also attended field days and workshops about oilseed crops and conservation agriculture.

Improving animal health and market access for poor livestock producers

Poor farmers raising small ruminants—sheep and goats—in the West Asia and North Africa (WANA) region face major difficulties. Veterinary and extension support services are scarce.

Preventive drugs and vaccines are expensive. Furthermore, farmers have little knowledge of the diseases their animals suffer. As a result, they have little interest in inspecting them or in reporting infections. These factors, coupled with poor information on markets, inefficiency, and high production and transaction costs, mean that they do not get good prices for their animals or animal products.

Collecting information about animal-health and marketing constraints in Tunisia (Fahs district), as part of an ICARDA–ILRI project that aims to raise livestock producers' incomes.

Unhealthy animals brought to markets like this one in Sudan cannot be exported. ICARDA and ILRI are therefore working to improve the health of small ruminants, so that poor livestock producers can profit from valuable export markets.

In 2005, researchers at ILRI and ICARDA investigated the difficulties poor farmers face in producing and marketing small ruminants in Jordan, Syria, Sudan, and Tunisia. They used participatory approaches to identify problems along the market chain—from producer to consumer.

Stakeholders in the market chain were categorized into seven groups: villages and communities; households and flock owners; markets; traders; slaughter houses; quarantine facilities; and veterinary clinics. Trained data collectors then administered questionnaires to the seven groups in each of the four countries.

Inadequate veterinary services, too few veterinarians, lack of diagnostic facilities, lack of clinical equipment, and inadequate training for veterinarians were reported to be constraints in all four countries. All countries also reported that lack of extension for farmers—both for animal health and marketing—was a limitation. Table 2 summarizes the constraints identified for each country. Research on these con-

Table 2. Animal health and marketing constraints in Jordan, Syria, Sudan, and Tunisia.

Country	Animal health-related constraints	Marketing constraints
Jordan	1. High neonatal mortality 2. Little diagnostic capacity or disease surveillance among veterinarians and farmers 3. Inadequate extension for farmers	1. Weak extension 2. Lack of marketing facilities 3. Marketing regulations not enforced
Sudan	1. Diseases: Peste des petits ruminants (PPR), sheep pox, and heartwater 2. Inadequate services due to lack of staff training 3. Inadequate extension for farmers	1. High cost of production 2. Lack of a marketing authority 3. Regulations concerning standards not enforced
Syria	1. Diseases: enterotoxaemia, pneumonia 2. Abortion 3. Lack of fodder 4. Lack of extension	1. Few markets 2. High cost of production 3. Large distance to markets
Tunisia	1. Lack of disease and health education for farmers 2. Low vaccination rate among poor producers compared with national average 3. Absence of regular veterinary services and control and sanitary procedures	1. Lack of information on marketing channels 2. Lack of quality-grading system for animals destined for market 3. No standardization of taxes: many levies exist which inflate animal prices

straints—and ways to overcome them—will continue in 2006.

Researchers also found that the private sector provides most veterinary services in all four countries. Jordan has 288 private veterinarians compared with 35 in the public sector. Similarly, most veterinary drug stores are privately owned. This was the case for all 75 stores surveyed in Jordan and all 24 surveyed in Sudan.

New fodder technologies to generate income

In the dry areas of the CWANA region, population growth has boosted demand for meat and dairy products, while urbanization has reduced the area available for grazing. This has led to a boom in peri-urban and urban meat and milk production systems. As a result, markets for irrigated and rainfed fodder are flourishing in most urban centers in the region. However, for farmers to benefit from this market opportunity they need to improve both the quantity and quality of fodder they produce.

Researchers at ICARDA and the Lebanese Agricultural Research Institute (LARI) therefore evaluated forage legumes and cereal–legume combinations that could give high yields of good-quality fodder. Such technologies aim to help poor farmers maximize their profits.

Identifying high-yielding native alfalfas

Farmers throughout the region already grow alfalfa (*Medicago sativa*), as this legume is the most profitable fodder crop available. However, little is known about the productivity of alfalfa lines native to the region. Researchers therefore compared the yield of two native alfalfa lines (54 and 597) from Syria with that of a released cultivar from Europe. They found that the two native alfalfas gave significantly higher dry matter yields than the European cultivar at the second, third and fourth cuts after planting (Fig. 1).

Although the dry matter yield of the native alfalfas declined by 22% for line 54, and 23% for line 597 from the first to the fourth cut after planting, the yield of the European alfalfa declined much more—by 35%. The overall yield of the native alfalfas over several cuts was therefore higher than that of the European alfalfa.

On average across the four cuts, the more productive of the two

ICARDA researchers are improving fodder-crop yields to satisfy the growing demand for feed from peri-urban milk and meat production systems like this one.

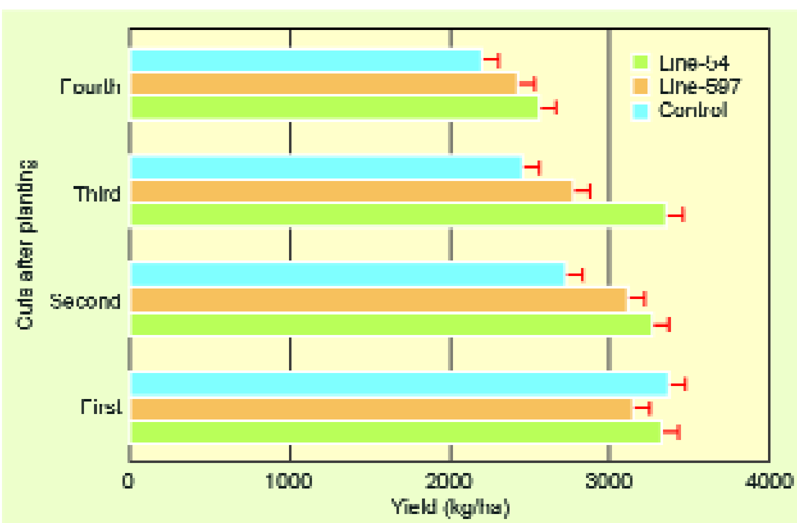


Fig. 1. Dry matter yield of two native alfalfa lines (54 and 597) and a European cultivar (control) at Terbol, Lebanon, in 2005.

native alfalfas, line 54, yielded 15% more dry matter than the European alfalfa. It therefore has good potential for market-oriented hay production.

Evaluating improved vetches

Recently introduced fodder production systems based on vetches (*Vicia* spp.) in combination with barley (*Hordeum vulgare*) and oats (*Avena sativa*) are also popular with farmers. However, most of the vetch cultivars used gave poor yields.

To find higher yielding options, researchers from ICARDA and LARI evaluated the performance of improved lines of common vetch (*V. sativa*) and narbon vetch (*V. narbonensis*) in conjunction with cereals. They found that common vetch produced more dry matter than narbon vetch (Fig. 2) in combination with barley or oats.

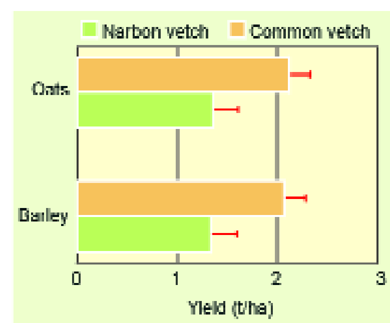


Fig. 2. Dry matter yield of improved narbon vetch and common vetch lines in combination with oats and barley at Kfardan, Lebanon, in 2005.

Growing high-yielding alfalfa, and improved lines of common vetch in combination with cereals, could therefore help farmers produce more forage and benefit from the growing market for fodder.

Phosphogypsum: a soil conditioner for improving barley yields

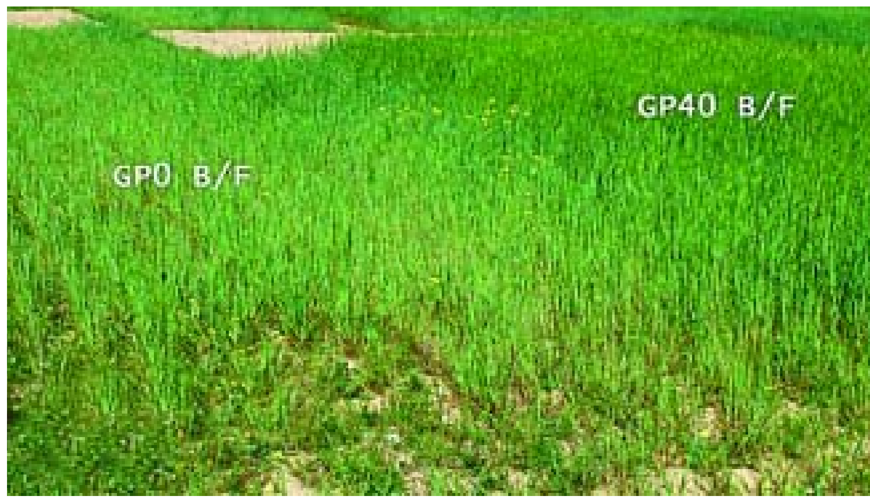
Phosphogypsum is a by-product of phosphorus fertilizer production which is available in large quantities in Syria and can be used as a soil conditioner. Working in the Khanasser Valley, researchers and farmers together designed a study to assess whether phosphogypsum improved the physical and chemical characteristics of soils in continuous barley cropping systems and barley–fallow rotations over four years (2001/02 to 2004/05).

The study assessed the effect on barley yields of one application of phosphogypsum (at different doses), at sowing of the first season only. A control (no phosphogypsum) was used for comparison. It also compared the effects of these different phosphogypsum treatments with the effect of applying phosphorus fertilizer (P_2O_5) every year. Researchers also analyzed the costs and benefits of using phosphogypsum and phosphorus fertilizer.

Effects of phosphogypsum on yields

In continuous barley systems, average grain yields over the four-year period in the two phosphogypsum treatments were 37% and 49% higher than in the control (Table 3). In barley-fallow rotations, average grain yields in the phosphogypsum treatments were 45% and 55% higher than the control over the same period (Table 3).

Importantly, although phosphogypsum was only applied once during the 4-year period, this single treatment raised yields over all four years. In the continuous barley cropping system, for example, treatments with 20 t/ha and 40 t/ha phosphogypsum yielded 48% and 67% more grain, respectively, than the control in the first year, and 42% and 63% more in the fourth year. The barley–fallow rotation showed a similar trend of raised yields over the four-year period.



In barley-fallow rotations, average grain yields of barley fields treated with phosphogypsum were much higher than those not treated.

Comparing phosphogypsum and P fertilizer

Researchers also investigated the effect of applying P fertilizer every year in the continuous barley cropping system. In the first year, barley yields in plots treated with phosphogypsum were far higher

Table 3. Effects of phosphogypsum on barley yields in continuous-barley and barley-fallow cropping systems, Khanasser Valley, Syria. Figures are mean over four years, 2001/02 to 2004/05.

Cropping system/treatment	Grain yield (kg/ha)	Increase in grain yield compared with control (%)	Total biomass (kg/ha)
	Average (SD)	Average	Average (SD)
Continuous barley			
Control (no treatment)	925 (655)	na	1825 (1390)
P_2O_5 (50 kg/ha)	1310 (700)	42	2940 (1735)
Phosphogypsum (20 t/ha)	1265 (755)	37	2435 (1620)
Phosphogypsum (40 t/ha)	1375 (825)	49	2790 (1935)
Barley-fallow			
Control	1255 (775)	na	2470 (1755)
Phosphogypsum (20 t/ha)	1820 (1125)	45	3630 (2360)
Phosphogypsum (40 t/ha)	1940 (1115)	55	3920 (2360)

na: not applicable; SD = standard deviation than in the plots treated with P fertilizer (40% more total biomass and 36% more grain). However, yields in the phosphogypsum plots decreased over time. By the fourth year, biomass yields were 3% less in the plots treated with phosphogypsum than in the plots treated with P fertilizer, and grain yields were 1.5% less.

Importantly, however, even though annual applications of P fertilizer may give slightly higher yields over a four-year period than one application of phosphogypsum, the cost of applying P fertilizer each year is beyond the means of many farmers. But farmers can afford to apply phosphogypsum once every four years. This would raise yields almost as much as annual applications of P fertilizer and cost much less.

Researchers found that, as well as fertilizing the soil, phosphogypsum also improves its physical condition—which is particularly good for early crop growth. In addition, soil moisture (at a depth of 0-60 cm) increased from 20% to 22%. This makes phosphogypsum use valuable during the flowering and grain-filling stages—particularly in dry seasons such as 2001/02. By contrast, applying P fertilizer had no effect on soil moisture compared with the control.

Assessing the costs, risks, and benefits

The cost of transporting phosphogypsum is 500 Syrian Pounds (about US$10) per ton. A partial cost–benefit analysis, taking transport costs into account, showed that farmers would not benefit from using phosphogypsum in the first year. But, they would benefit in years 2 to 4. By contrast, farmers would gain little—or even lose, depending on the rainfall in a particular season—from applying P fertilizer each year.

Another issue is safety— phosphogypsum is slightly radioactive. During the trials, however, researchers found that its use hardly raised radiation levels in the upper soil profile. Furthermore, radiation levels in barley straw and grain did not seem to be affected at all—they were below the detectable limit (about 2 Bq/kg of dry matter).

Based on the higher yields, and the fact that the study showed that there is no danger from higher radiation in crops treated with phosphogypsum, the Ministry of Agriculture, the Atomic Energy Commission of Syria, and ICARDA are now looking at ways of encouraging farmers to use phosphogypsum as a fertilizer and soil conditioner.

Assessing farmers' views on phosphogypsum use

ICARDA conducted a participatory technology evaluation to assess farmers' perceptions of the impact of phosphogypsum on barley crops. They also identified technical, economic and other related problems that the farmers faced during the trials.

Farmers rated phosphogypsum as very effective for raising barley yields under both continuous barley cropping and barley–fallow rotations. They observed that the soil moisture levels in the top 20 cm of the soil profile were higher in the 40 t/ha phosphogypsum treatment than they were in both the 20 t/ha and the no phosphogypsum treatments. This, they believed, was one of the reasons why phosphogypsum use, as well as P fertilizer treatments, gave higher yields.

All the farmers surveyed were interested in using phosphogypsum provided transport costs were no more than 100 Syrian Pounds (SP)/t. Most farmers (77%) would apply just 20 t/ha if they had to bear the cost themselves, and only 23% would apply 40 t/ha. However, they would all apply 40 t/ha if they did not have to pay.

By chance, the application of 10 t/ha of manure on a farmer's field next to one of the experimental fields allowed researchers to compare the effects of manure versus phosphogypsum. The manure happened to be applied at the same time as phosphogypsum was applied on the experimental field. After three years, the field treated with manure was indistinguishable from the field treated with phosphogypsum. This means that phosphogypsum compares favorably with manure in raising barley yields. However, only a few farmers (18%) applied manure because it is expensive (7,000-10,000 SP/ha).

Overall, phosphogypsum raises yields, but costs less than P fertilizer or manure and needs to be applied only once every four years. Farmers have therefore proposed that policymakers should find solutions to the high cost of transporting supplies to their farms.

Maintaining soil fertility and sustaining production in CAC

Benefits of conservation tillage in different farming systems

In Central Asia and the Caucasus (CAC), decades of intensive plowing have depleted soil organic matter. This has increased soil erosion, and reduced the soil's fertility and its ability to hold water. ICARDA and its national research partners have therefore been studying conservation tillage, in order to identify practices that reduce soil disturbance and thus maintain fertility and boost yields.

This research has shown that conservation tillage can feasibly be used in spring wheat cropping systems without reducing grain yields. In fact, farmers in northern Kazakhstan are now using conservation tillage methods on around 100,000 ha of spring wheat. Research has, however, shown that conservation tillage is less suitable in areas with heavy soils, as these need to be broken up by deep tillage. The same is true in areas where the soil remains frozen in early spring, as melt-water from snow simply runs off untilled frozen soils.

In rainfed winter wheat cropping systems, a trial conducted from 2002 to 2005 showed that conservation tillage using V-type sweeps (which cut the soil without turning it over) produced similar grain yields to conventional moldboard plowing to the same depth. Another technique, tested over a four-year period in the Krasniy Vodopad area (southern Kazakhstan), involved tilling the ground only at sowing. Researchers found, however, that this did reduce grain yields slightly in comparison with deep tillage (using either a sweep or moldboard plow). The reductions were due to soil compaction, greater competition from weeds, and the fact that less nitrate was available in the soil. Despite these limitations, however, this system is being adopted by some farmers in southern Kazakhstan because it saves fuel and labor.

In irrigated cotton–wheat systems, ICARDA studies conducted between 2001 and 2002 showed that broadcasting wheat seed into standing cotton and then incorporating it into the soil with cultivators also saves fuel and labor without affecting wheat yields significantly. This minimum tillage practice is now being used on 50-60% of the area sown to wheat in Uzbekistan and Tajikistan and on 20% of such areas in Turkmenistan.

Conservation tillage applied in northern Kazakhstan, leaving the residues on the soil surface.

During 2004 and 2005, researchers also conducted trials of irrigated winter wheat planted in raised beds on farms in Azerbaijan and southern Kazakhstan. The technique increased yields to some extent, and also provided major savings on seeds (50%) and water (30%). Raised beds could be adopted over a larger area if the planting equipment needed could be manufactured in Kazakhstan. ICARDA is therefore helping to establish a joint venture between Indian and Kazakh manufacturers.

ICARDA has also been testing no-till planting machines manufactured in India and Brazil in Kazakhstan, Uzbekistan, and

Locally made no-tillage direct drill equipment for grain crops in northern Kazakhstan.

Tajikistan. These machines could be used for planting winter wheat and cotton, both separately and in double-cropping systems. In Uzbekistan, researchers have also obtained promising results when testing newly-designed equipment for conservation tillage in cotton fields and wheat stubble.

Diversifying cropping systems

Avoiding monocropping and diversifying the range of crops farmers grow also helps to maintain soil fertility and is important for sustainable production. ICARDA's work in both irrigated and rainfed farming systems in CAC countries is helping to introduce the new crops needed.

Different crop options for replacing monocropping systems for diversification in Central Asia and the Caucasus.

Spring wheat cropping systems usually involve a rotation of wheat with barley, followed by a summer fallow once every three to five years. ICARDA researchers have devised a new system in which the summer fallow is replaced by small-grain crops (like oat, millet, and buckwheat), food legumes (dry pea, chickpea, and lentil) and oilseeds (sunflower, rapeseed, and mustard).

The Center has also shown that high-input systems can significantly increase the yields of the crops introduced to replace the summer fallow. For example, chickpea grown in rainfed areas with a high-input technology package yielded almost three times as much as chickpea grown under a low-input regime (Table 4). The high-input technologies included intensive snow-management practices, efficient weed control and the application of both phosphorus and nitrogen fertilizers. The medium-input treatment reflected the cultural practices commonly used in the area, while the low-input treatment simply involved seedbed preparation before sowing.

However, farmers are reluctant to diversify into food legumes for two reasons. First, markets for these crops are not yet well developed. Second, they know little about the new crops, as they are used to growing only spring wheat. Policies that promote the development of internal and external markets for these crops could encourage farmers to grow them. Sunflower is one example of a crop that farmers are adopting because demand is strong, providing a ready market and a good price. Government policy can help to boost production of these new crops. For example, from 2006 to 2008, Kazakhstan's government will provide subsidies to producers and processors to promote large-scale rapeseed production.

In rainfed winter wheat cropping systems, safflower, another oilseed crop, has proved to be a very good cash crop and is replacing wheat over a significant area in southern Kazakhstan. Safflower is also being adopted in dryland areas of Uzbekistan, as far as government policies permit. In long-term trials led by ICARDA in rainfed areas of southern Kazakhstan, introducing alfalfa improved the productivity, efficiency, and sustainability of farming systems. However, shortages of seed and of the machinery needed for seed processing are preventing farmers from adopting alfalfa.

In irrigated winter wheat cropping systems, ICARDA has found that soybean and common bean are the most promising alternative crops.

Table 4. Chickpea grain yield (t/ha) under high-, medium- and low-input systems at Shortandy, Kazakhstan, 2001-2005.

Technology	Chickpea grain yield (t/ha)					
	2001	2002	2003	2004	2005	Mean
Low input	0.55	1.04	1.05	0.22	0.46	0.66
Medium input	0.97	1.28	1.31	1.01	1.14	1.14
High input	1.70	1.98	1.57	2.31	1.64	1.84

Indeed, in Kazakhstan the area cropped to soybean increased more than eight-fold (from 5,000 ha to 43,000 ha) between 2003 and 2005 as market conditions improved. This trend is likely to continue because Kazakhstan's government has decided to promote soybean production in 2006. Likewise, in Kyrgyzstan, the areas of both soybean and common bean are increasing.

In irrigated cotton–wheat systems, the best way to introduce alternative crops is to plant them straight after the harvest of winter wheat (the main crop), on land that would otherwise be left fallow until cotton is planted the following year. In Uzbekistan, Kazakhstan, and Kyrgyzstan, ICARDA has shown that growing food legumes (like mung bean, soybean, common bean, and groundnut) and other new crops (maize, sesame, and melon) can provide additional income for cotton–wheat farmers. These crops also improve the sustainability of cotton–wheat systems. However, most CAC governments do not promote double cropping because an additional crop competes with cotton for water. Turkmenistan is the only country that promotes double cropping, that of sugar beet with rice.

Assessing genetic relationships among Iraq's date palm varieties

Date palm (*Phoenix dactylifera*) was one of the first fruit trees ever to be cultivated. It is commercially important, mainly in the Middle East and North Africa—where it is also valued for its social and religious significance. Until 1991, Iraq was the leading producer of dates and had the world's largest date 'forest', on the Fao Peninsula. However, many date palms were destroyed during the Gulf and Iran–Iraq wars. More were lost when the southern marshes were drained. These losses threaten to erode date palm's genetic diversity.

Little research has been done to characterize date palm germplasm. Such characterization is important, however, to identify varieties, breed improved cultivars, and conserve genetic diversity.

Growing genetically diverse varieties helps to minimize the effects of biotic stresses, as some varieties are more tolerant than others. Diversity among parents also creates progenies with genetic variations that can be used for further selection and molecular mapping. ICARDA is therefore working to develop molecular markers to help characterize date palm varieties. Researchers extracted DNA from the young leaves of 18 reference varieties collected from the Ministry of Agriculture farm at Al-Latifia, Iraq. They then used amplified fragment length polymorphism (AFLP) markers (Fig. 3) to

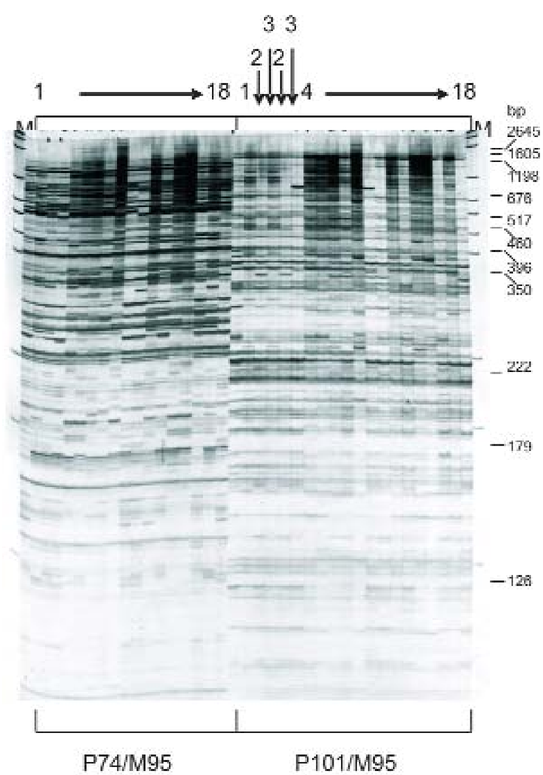


Fig. 3. Amplified fragment length polymorphism (AFLP) banding patterns of 18 date palm varieties from Iraq using primer combinations P74/M95 and P101/M95. Numbers on the right indicate the fragment size of molecular weight markers (lane M) in base pairs (bp). Lanes 1-18 show the banding patterns of the varieties Barhi, Um Al-Dihen, Usta Umran, Maktom, Guntar, Khestawi, Zahdi, Sakri, Khedrawi, Chipchab, Ashrasi, Jamal Al-Dean, Shwethi Asfar, Zuber, Bint Al-Suda, Bream, See Sandali, and Tebarzal, respectively. To test reproducibility, the AFLP analyses of the Um Al-Dihen (#2) and Usta Umran (#3) varieties were repeated and samples were loaded side by side.

characterize the varieties and estimate their genetic relationships.

The study identified 122 polymorphic AFLP loci, with an average of 17.4 polymorphic loci per primer combination. All varieties could be uniquely identified using any one of four primer combinations:

P101(aacg)/M95(aaaa),
P74(ggt)/M95(aaaa),
P73(ggg)/M95(aaaa), and
P100(aacc)/M95(aaaa).

Values for Jaccard's genetic similarity index ranged from 0.108 to 0.756, indicating moderate to diverse genetic relationships between the varieties (Fig. 4).

Most of the recessive AFLP loci in Chipchab were fixed, whereas in Jamal Al-Dean most of the loci were heterozygous. In the other 16 varieties, the loci were in between fixed and heterozygous. Based on unweighted pair group method analysis (UPGMA) at 27% similarity, the varieties were then sorted into two groups: one containing 7 varieties and the other 11 varieties. This means that molecular markers can be used to effectively identify date palm varieties and their genetic relationships.

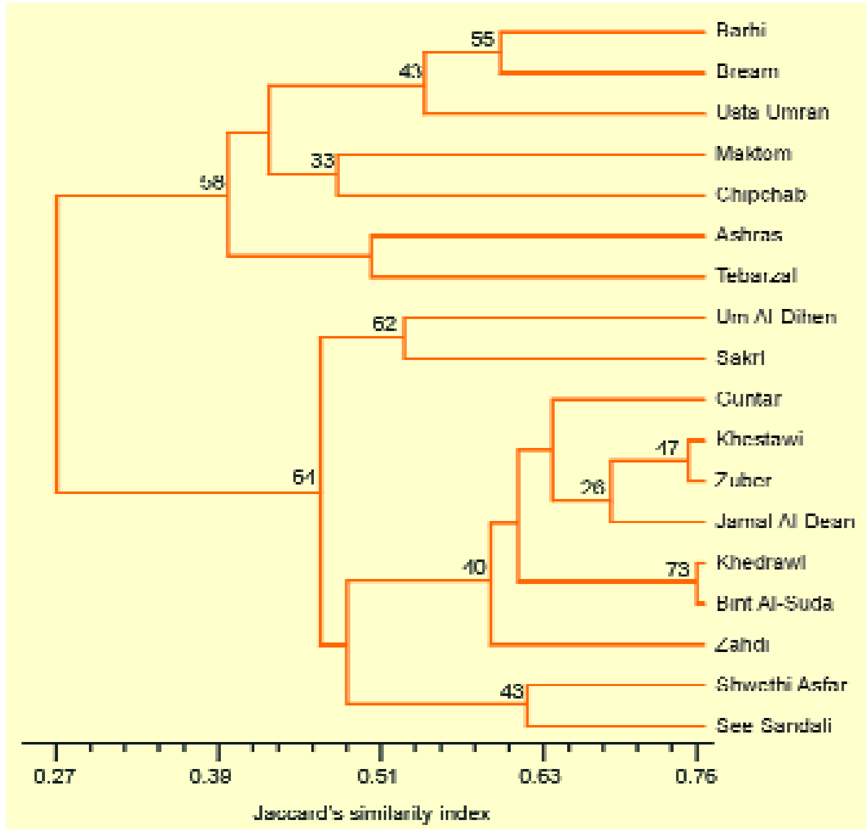


Fig. 4. Relationships between 18 date palm varieties from Iraq as indicated by Jaccard's genetic similarity index. The values on the branches are the bootstrap probabilities.

Growing crops without soil

In much of the Arabian Peninsula, traditional agriculture is simply not viable. Given the harsh weather conditions, acute scarcity of water and lack of good arable land, crops are likely to fail in most years. One alternative is to produce high-quality cash crops using soilless culture or hydroponics – the focus of a collaborative project by ICARDA and the NARS of seven countries in the Peninsula.

The project is studying different hydroponics systems at research centers in Oman, Saudi Arabia, Bahrain and Kuwait, in order to identify the best options (which crop, what management technique) for each region.

Hydroponic strawberry production at Rumais Research Station in Oman.


Producing high quality cucumber using hydroponics at a private farm in Oman.

Hydroponics allows growers to tightly control the environment, and schedule their harvests precisely, thus improving yield, quality and price. Best-bet options identified at research centers are now being transferred to pilot growers for further on-farm studies. Growers have found that, as on research stations, hydroponics results in high water-use efficiency, large savings in fertilizers and water, increased production per unit area, better quality produce, earlier-maturing and more uniform plants, compared to production on soil. It also eliminates the need for costly operations such as sterilization, seed-bed preparation and weed control.
The vertical soilless production technique for strawberry, which increases production, reduces cost and saves water, has been studied for four years in Oman and Kuwait. A study in Kuwait showed that hydroponics cut production costs by 60% compared to soilbed cultivation.

Introducing protected agriculture in Yemen

The natural resource base in Yemen – already fragile – is further threatened by over-exploitation. ICARDA is working with the national research and extension services and other partners to help develop and promote more sustainable technologies.

Water management

One key area is water. The government has built several dams and water reservoirs to harvest and distribute water for irrigation. But in the absence of an irrigation network, the benefits are restricted to farmers living very near a reservoir. In addition, these farmers use inefficient surface irrigation methods, further depriving other users. ICARDA and the Agricultural Research and Extension Authority (AREA) are jointly conducting on-farm research and demonstrations at the Mikhtan Dam site, under the project "Sustainable management of natural resources and improvement of major production systems of the Arabian Peninsula".

The project aims to improve water-use efficiency by introducing two new technologies: modern irrigation techniques (bubblers) to irrigate grape vines, and intensive protected agriculture systems for high-quality cash crops. Scarce water will be judiciously used, combined with Integrated Production and Protection Management (IPPM) practices, to maximize yield per unit of resources (land, water, etc.) used. The new technologies are being simultaneously tested and demonstrated at a greenhouse (54m x 9m) in Sana'a, Yemen, where cucumbers are produced under drip irrigation, using IPPM. The technologies are also being scaled out to pilot farmers. Preliminary results show that IPPM has significantly increased returns and reduced pesticide use; irrigation efficiency has been as high as 93%.

Researchers compared the economics of greenhouse cucumbers produced with and without IPPM. Water-use efficiency (production per cubic meter of water) and yield (production per unit area) were substantially higher with IPPM. For example, water-

Water from the Mikhtan Dam in Yemen is being used more efficiently, increasing output and farmers' incomes while conserving scarce resources under protected agriculture.

use efficiency was 32.5 and 30.6 kg/m^3 in two IPPM greenhouses at two locations, versus 21.8 and 12.1 kg/m^3 in the "control" greenhouses at the same locations. Similarly, IPPM resulted in 18% higher total yield and better pest management. At one location, the IPPM greenhouse was free of insects while the control greenhouse was severely infested with white fly and thrips. At the other location, effective control required six sprays in the IPPM greenhouse compared to 18 sprays in the control. On average, the return on investment was 157% with IPPM and 112% without it.

Mountain terraces in Yemen

The rainfed terraces of Yemen – where much of the country's food is produced – are trapped in a vicious cycle. Agriculture offers poor returns, so people (especially men) leave the rural areas to find work elsewhere. This means less maintenance and more degradation of the terraces… and lower returns and still more migration. Attempts to encourage farmers to remain on the land have only been successful where irrigation water is available and cultivation of cash crops is possible.

ICARDA is leading a 2-year project funded by the French-Yemen Food Aid Program, which aims to introduce protected agriculture technology for the production of cash crops (mainly cucumber and tomtao) in the mountainous Taiz region. The project will install simple greenhouse structures at selected pilot sites, to produce high-value cash crops. This will increase the incomes of poor households, improving their ability to maintain the terraces and reduce degradation. It will also enable farmers to use limited water resources more efficiently. The project is based on active community involvement. Farmers will participate at all stages. The project will provide appropriate technical information and training; at the end of the project the participating farmers will serve as key agents for dissemination.

The pilot phase began with 17 farmers in three areas. These farmers were trained, their socio-economic profiles were carefully studied, and the greenhouse structures installed (farmers participated in the insulation and assembly, gaining additional on-the-job training), ready for planting.

Training is a key project element. Using the training-the-trainers approach, ICARDA staff and consultants trained extensionists, agricultural engineers and technicians on greenhouse installation and preparation for producing cash crops. On-the-job training was conducted for farmers; and five training manuals in Arabic were developed, covering greenhouse installation, nursery management, irrigation and fertigation, soil preparation, and IPPM.

Introducing protected agriculture in Afghanistan

Small-scale farmers can substantially improve their incomes by diversifying into horticulture; for example, growing vegetables for sale. But horticulture is not profitable without irrigation – and few farmers in the dry areas of Afghanistan have reliable access to irrigation. With funding from USAID, ICARDA and its partners are helping to promote "protected agriculture" technologies, enabling farmers to profitably grow vegetables even in dry rainfed areas. Protected agriculture allows high-intensity (but affordable and sustainable) production of cash crops on marginal or otherwise non-productive land. It can generate returns high enough to compete with Afghanistan's main cash crop, the opium poppy.

The project operates at pilot sites in six provinces: Kabul, Kunduz, Parwan, Ghazni, Helmand and Nangarhar. At each site, pilot farmers were selected after discussions with the community. By April 2005, 35 greenhouses (size 270 m^2) were installed, and every pilot farmer had received production materials, fertilizer, seeds, and extensive training on greenhouse management and crop handling. During the growing season, the project conducted a series of workshops and Farmer Field Schools, where the pilot growers worked with extension agents and project staff to master the new technology. The greenhouses are being fully utilized, mainly for growing cucumber, tomato, lettuce and peppers; project staff visit regularly to monitor progress and provide advice.

The focus of training and capacity building activities is the Protected Agriculture Center in Kabul. It was established by the project in 2005 for research, training, demonstrations, and provision of technical support and advisory services. The Center has trained over 350 people (growers, extension agents, NGO personnel and others) on different aspects of protected agriculture. Ten others were trained in Oman and Egypt, where protected agriculture facilities and expertise are more advanced. This is the first time that a project has sent Afghan growers overseas for training.

Afghan growers receiving hands-on training on crop handling and greenhouse management

The project has also produced a series of manuals in the local language, covering subjects such as greenhouse installation, climate control, drip irrigation, crop nutrient/management requirements, fertigation, crop nurseries, and vegetable production methods. The demonstration greenhouse at the Center has proved highly effective in generating farmer interest and promoting adoption. The first harvest (1.7 tons of cucumbers) took only 75 days, and was sold for US$1280.

Sustainability and expansion of the project will depend mainly on the cost of setting up the greenhouses, which are currently imported. The project established a workshop to manufacture single-span greenhouse structures locally, to cut costs. We are now able to build good quality structures, 40% cheaper than the imported structure, using mainly local technicians and locally purchased material.

An economic analysis compared cucumber production in greenhouses versus open fields. Greenhouse production gives four times the output and five times the net income per unit of land, compared to field production. Equally important, it gives nine times the net return per unit of water.

During a mid-season workshop in July 2005, growers were confident the new technology would work, and positive about the future. Mohamed Qasim, a grower from Helmand, said: "With opium, we can produce one crop per year and it requires lots of labor. But we can produce 2-3 crops of cucumber from a plastic house on a small piece of land with less labor and more income. I think if you give farmers a plastic house they will stop growing opium."

Mega-Project 5
Poverty and Livelihood Analysis and Impact Assessment in Dry Areas

Introduction

Poverty, in its broadest sense (income, water, educational opportunity, gender equity, and vulnerability) is widespread in the dry areas, particularly in the CWANA region. A deeper understanding of the determinants of poverty, and of the livelihood strategies adopted by rural communities, is necessary to continually refine the targeting of ICARDA's research, enhance and track its impact, and identify pathways out of poverty.

Mega-Project 5 seeks to contribute to the identification of research pathways to implement technological, institutional, and policy options to reduce rural poverty in the dry areas globally. This is being done through, among other approaches, improved characterization of the rural poor (assets, context, depth and duration of poverty, vulnerability, basic needs, and choice of livelihood strategies) in relation to agriculture and the environment, and studying patterns of adoption and the impact of improved varieties and natural resources management practices. Another important dimension is understanding the structure, conduct and performance of domestic markets for agricultural commodities across different countries to evaluate the implications of market imperfections for small farmers. Efforts are directed toward the involvement and active participation of end-users in development, testing and verification of new technologies, so that relevance and adoption by individuals, communities and institutions of new options and pathways is maximized. Frameworks and methodologies for participatory and community-based research are being developed and implemented in partnership with NARS to enhance the impact on rural livelihoods.

Characterizing rural livelihoods: targeting research to reduce poverty in marginal areas

Research and development work often neglects dry marginal environments. Because of low and erratic rainfall, infertile soils, limited groundwater, and land degradation, these areas contribute only small amounts to national production. As a result, they recieve less agricultural investment from governments for strategic crops and farming technologies.

Rural households in dry marginal areas are also poorly served by social services and basic infrastructure. Many depend on wages from unreliable off-farm employment. As they have few capital assets, they are also regarded as high-risk borrowers. As a result, when they need loans they are forced to pay excessive interest to local money lenders.

Classifying rural livelihoods in Khanasser Valley, Syria

To help identify technologies and institutional and policy options that could help people living in dry marginal areas, researchers conducted a rural livelihoods study of households in the Khanasser Valley, Syria. This integrated study used qualitative and quantitative surveys, rapid appraisal interviews, and wealth-ranking exercises based on local people's assets and perceptions.

Livelihood surveys help understand the context of rural poverty in marginal dryland areas.

To better understand the different dimensions of poverty in the area, researchers collected information on five categories of household resources. These resources were 'natural' (land, water); 'physical' (farm equipment, livestock); 'financial' (cash, use of micro-finance and loans); 'human' (labor, level of education, migration); and 'social' (organizations, associations and connections to migration options).

Researchers then classified households into three types, based on their resources and their main livelihood strategies. The household types identified were (1) agriculturists who integrate crop production with fattening lambs and also work for wages; (2) wage-laborers, who own little or no land, mostly rely on off-farm earnings and migrate for employment; and (3) pastoralists who rely on extensive herding, occasionally fatten lambs intensively, and also migrate for employment. Each of these three groups has two subgroups (Table 1).

Researchers found that per capita disposable incomes in the study area were below US$2/day, while those of wage-laborers (50% of households) were less than US$1/day. The poorest households—those with lowest per capita income and few assets—were the wage-laborers who farmed a little land, the wage-laborers who worked as herders, and the pastoralists with no additional income from employment. These should be considered the poorest of the poor.

How different household types would benefit from agricultural research

In general, the study found that wage-laborers rely on farming to a very small extent, and that people in this category were most likely to give up farming for other occupations. Researchers also found that about 30% of households in the study area (mainly wage-laborers with no agricultural assets) would benefit little from agricultural research, although they might benefit from the spillover effects of such research.

This means that agricultural research centers may not play a direct role in alleviating poverty in these groups. However, they are well-placed to identify and promote other options for improving

Table 1. Household typologies in the Khanasser Valley, Syria.

Capital			Wage-laborers		Agriculturists		Pastoralists	
			With farming	Herders	Without off-farm labor	With off-farm labor	With off-farm labor	Little or no off-farm labor
Social, human	People	Average persons /household	9.17	6.64	6.75	11.29	10.43	11.00
	Educated males	% males	68	66	88	63	61	32
	Educated females	% females	46	28	11	30	15	33
	Members of associations	% households with membership	25	9	50	52	57	80
	Migrant members	% households with migrants	75	73	0	62	43	0
Natural, physical	Land owned or used	Total (ha)	6.83	3.73	7.55	11.30	0	0
	Well owners	% of total households owning wells	58	9	25	71	71	40
	Sheep	Head	4.2	3.7	91.8	62	79.3	41
Financial	Average credit use	US$/year/ household	490	310	810	415	1420	1280
	Per capita income	US$/day[1]	0.82	0.48	1.72	1.30	1.43	1.15
Main livelihood activities	- Crop production	% income	9	5	23	9	0	0
	- Livestock		7	19	29	13	82	76
	- Sheep fattening		0	0	48	50	3	15
	- Off-farm labor		84	76	0	28	15	9

[1] Based on an exchange rate of SP51=US$1 (2002).

these people's livelihoods. Ways forward include promoting initiatives to develop skills, create jobs in non-farm sectors, and improve access to capital through micro-finance schemes. Pastoralists could also benefit from research and development that considers their nomadic existence, as they rely on extensive herding in remote steppes where there are few opportunities for off-farm work.

Agriculturist households were relatively better off, as they had sufficient land and labor to make a living mainly from farming. They were, however, still poor. This group would benefit both directly and indirectly from agricultural research. They are, for example, more likely to adopt new crop and livestock production technologies because (1) they have access to water and land, (2) they are better educated, and (3) they have more household members who are wage earners. These households account for about 45% of those in the Khanasser study area, and are the most likely to be able to use their resources to improve their livelihoods.

Wage-laborers who farm less than 4 ha (about 25% of households) were placed in between the poorest and the relatively better-off households. They have enough land to be able to increase their agricultural income if they could farm more intensively, and could benefit directly from new technologies to improve crop and livestock production. They could take advantage of both direct and indirect opportunities to improve their livelihoods without leaving farming. Agricultural research can and should target these households.

Participants at a workshop on rural livelihood analysis at ICARDA.

Several technologies show potential impact in the dry marginal areas. These include feed options such as production of vetch for lamb fattening and dairy flocks, intercropping of *Atriplex* shrubs with barley, improved barley and wheat varieties, water harvesting techniques for production of olives on hillslopes, and modern irrigation practices for small-scale vegetable production. Institutional innovations such as micro-finance can help the poorest households participate in the more profitable enterprises of sheep production.

Rural households in dry marginal environments are not homogeneous. They have a variety of assets and capabilities. The household typologies and livelihood strategies identified in this study will help ICARDA focus on the research that will be most useful in lifting rural households out of poverty.

This study has shown how research for development can reach the dry marginal areas; and provided evidence of the diverse potential impacts on different household types depending on their asset base. The findings, as well as the approach used, will be relevant in other dry marginal areas.

Agrobiodiversity conservation and use: assessing impacts

Since 1999, ICARDA has been coordinating a five-year Global Environment Facility (GEF) funded project to promote *in situ* conservation of dryland agrobiodiversity and its sustainable use. The project, which ended in 2005, was implemented in Jordan, Lebanon, Palestine, and Syria. It focused on conserving landraces and the wild relatives of barley, wheat, lentil, alliums, feed legumes (*Lathyrus*, *Medicago*, *Trifolium*, and *Vicia* species), and fruit trees (olive, fig, almond, pistachio, plum, peach, pear, and apple).

A nursery established in Lattakia, Syria, for landraces and wild relatives of fruit and forest species.

Nationally, project activities were implemented by different research institutes in each of the countries involved: the National Center for Agricultural Research and Technology Transfer (NCARTT) in Jordan, the Lebanese Agricultural Research Institute (LARI) in Lebanon, the General Commission for Scientific and Agricultural Research (GCSAR) in Syria, and the Ministry of Agriculture in Palestine. Farmers and herders were fully involved throughout the project.

The project has increased awareness of the need to conserve agrobiodiversity at all levels. This has led tourism and education ministries to collaborate with relevant projects and non-governmental organizations. It has also prompted research institutions in Jordan, Lebanon, and Syria to implement their own agrobiodiversity programs, and has resulted in Jordan's Forestry Department and the Palestinian Authority's Ministry of Agriculture setting up agrobiodiversity units. The governments involved have also now officially recognized key sites rich in agrobiodiversity, via processes which took into account the needs and wishes of local communities.

The project has also collected many target-species accessions. These have been added to genebanks and databases developed to hold the results of ecological and botanical surveys in the countries involved. Importantly, standardized methods of managing these databases were also developed and shared between the partner countries. In addition, the project's efforts to encourage the use of the wild relatives of fruit trees in afforestation efforts led to the number of fruit-tree seedlings planted in Syria to rise from 30,000 in 1999 to 500,000 in 2003. To review the project's progress, a full socio-economic assessment of its impacts was conducted in 2004 and 2005.

Impacts on livelihoods

To assess the project's impact on livelihoods, ICARDA researchers and national partners surveyed 276 households that had participated in the project and 294 households which had not. These surveys were conducted in the eight project locations (two per country) in August and September 2004, using a questionnaire which had been tested in June 2004. This dealt with a range of topics and allowed researchers to characterize household livelihood strategies.

The researchers wanted to compare livelihood strategies, agrobiodiversity use, and incomes (1) within and across all the countries studied and (2) among poorer and better-off households. To do this, they used factor analysis to create a wealth index that took into account all five types of capital a household can have: human, natural, financial, physical, and social. The survey covered household assets such as cropland, rangeland, livestock, vehicles, and houses, as well as on- and off-farm incomes, and access to credit, cooperatives, and healthcare. Based on this, households were classified into four wealth groupings (quartiles), each corresponding to 25% of the range of values obtained for the wealth index.

Livelihood strategies

To benefit the people in an area, conservation practices and investments need to be appropriate to local people's livelihood strategies—as well as to agro-ecological conditions and the production systems being used. The project's impact assessment therefore considered the different sources of income used by households in the study areas. In all four countries, the poorest households (those in the lowest wealth grouping) mainly obtained their income from crop production, although off-farm labor and government employment were also important (Fig. 1).

By contrast, households in the highest wealth grouping mainly depended on the income obtained from selling livestock products and live animals, though they also practiced crop production, worked off-farm, and took advantage of government employment. Over all wealth groupings, livestock provided the main source of on-farm income in Jordan, while crops and fruit trees were the major source of on-farm income in Lebanon, Palestine, and Syria.

Simple water-harvesting techniques to conserve agrobiodiversity were demonstrated extensively to local communities.

Overall, off-farm income was an important source of livelihoods in all the target areas, accounting for 43-68% of household incomes. Clearly, although agriculture is not the only source of household income, it is still a major component of livelihoods in the dry areas.

Importance of target crops by wealth group

The agrobiodiversity project targeted different crops; their importance to the household depended on the wealth group (Table 2). Wheat and barley were more important for better-off farmers, while apricot and apple were more important to poor farmers. In all groups, fruit trees were generally more important to farmers than field crops.

Table 2. Importance of different crops targeted in an agrobiodiversity project, classified by wealth group.

	Wealth index category				
Country/crop	Lowest 25%	25-50%	50-75%	Highest 25%	All groups
Lebanon					
Grapes	6	9	13	6	8
Apricot	19	28	25	16	22
Apple	15	5	3	7	7
Olive	0	3	3	2	2
Wheat	5	7	14	9	9
Barley	3	6	6	11	7
Chickpea	3	6	5	7	5
Lentil	2	2		1	1
Syria					
Grapes	16	17	9	22	17
Apple	12	11	8	25	15
Olive	8	11	10	8	9
Wheat	15	19	27	16	19
Barley	7	6	8	2	5
Chickpea	7	13	14	15	13
Palestine					
Grapes	11	12	11	9	11
Apple	3				1
Olive	31	24	19	37	28
Wheat	23	38	28	37	31
Barley	0	0	6	3	2
Chickpea	0	0	0	3	2
Onion	3	9	11	0	6

Numbers show the percentage of sample farms growing a particular species under each wealth-index category.

This finding has important implications for national and international efforts to conserve agrobiodiversity. It suggests that the focus of *in situ* conservation of cereal crops should be on the fields of well-off farmers; whereas fruit tree conservation is more appealing for poorer farmers. Appropriate conservation strategies will improve the livelihoods of all farming groups, especially the poor, and directly contribute to poverty reduction.

Project impacts on agricultural incomes

The study found that average household incomes ranged from US$2200 to US$9000 per year, equivalent to a daily per capita income of less than US$1 to US$5.

Fig. 1. Sources of income for farm households in different wealth quartiles in Jordan,Lebanon, Palestine, and Syria.

In general, per capita incomes were around US$2/day in Jordan, Lebanon, and Jenin (Palestine), but less than US$2/day in Syria and Hebron (Palestine). Income from agriculture accounted for 32-57% of these amounts.

In the majority of cases, the households that had participated in the project had average agricultural incomes that were greater than those of non-participating households—by US$1148, US$1754, and US$1914 on average, in Syria, Jordan, and Lebanon, respectively.

Researchers also calculated Gini coefficients to assess the equity in incomes within participating and non-participating households in each country. The values were not significantly different, indicating that enhancing agrobiodiversity did not increase inequalities between poorer and more well-off farmers.

The results highlight the importance of agrobiodiversity conservation in improving the livelihoods of farming communities. However, to be effective, research should be based on the importance of targeted species to different farming groups. This study provides clear indications on such targeting.

Gender dimensions of conserving and using local agrobiodiversity

ICARDA's five-year West Asia Dryland Agrobiodiversity Project, which ended in 2005, promoted the conservation and sustainable use of local agrobiodiversity at eight sites in Syria, Lebanon, Jordan, and Palestine. To ensure that efforts were targeted properly, the project included work to analyze the gender-related aspects of agrobiodiversity use and management.

Men and women usually play different roles in the growing, collecting, processing, and selling of plants and plant products. Consequently they hold different knowledge about important wild species and genetic resources. Furthermore, women's knowledge, and the contributions that plants make to families' food supplies and livelihoods, tend to be ignored in rural-development efforts and are often not well understood.

Rapid rural appraisals and surveys of around 70 households at each project site were used to study women's and men's roles as resource users and managers. We found that both groups are responsible for different agricultural activities, and that women were intensively involved in agrobiodiversity management and conservation.

Women's roles

Women and children were mainly responsible for collecting medicinal plants. This was true in 75% of the households surveyed in Palestine (Table 3), and an even higher proportion in other countries.

Women were also responsible for processing agricultural crops and wild species to make food. This was true in 96 to 100% of households surveyed (Table 3).

Responsibility for the sale of medicinal plants, however, was shared by men and women. In Jordan, Syria, and Lebanon, 60 to 88% of women sold plants that they had collected and processed. In Palestine, however, this figure fell to 42%, because of security issues at the project sites.

Researchers also found that women play an important role in selecting, drying, and storing seeds. By implication, seed interventions targeted at women, could generate more income.

A woman in Ajloun, Jordan, tends her medicinal and herbal plants, which she established after receiving training offered by the project.

Wild species: gender-related benefits and responsibilities

The project also studied the uses of 37 types of wild plant, and determined whether women or men were responsible for collecting, processing, and marketing them. The species considered were either used to make herbal teas (for medicinal or everyday use), were eaten as food, or used as spices. *Khobayzeh (Malva sylvestris*), for example, was made into a popular dish in all four countries, while *Silybum marianum* and *Raphanus* sp. were often eaten in salads in Syria. *Rhus coriaria* was widely used as a spice in Jordan, Lebanon, and Syria.

Because knowledge of these species is shared between men, women, and children, the project took all these groups into account in its research, awareness-raising, and development activities. This involved working closely with schools, NGOs, and women's groups.

Market access for women

For women to earn money from selling the products they have collected or processed, they often need access to a market close to home. Researchers assessed how accessible markets were in and around the study sites.

In Lebanon, half the men and women surveyed were able to sell their products at a market in their own village. This figure dropped to around one-third and one-quarter of the people interviewed, respectively, in Palestine and Jordan – and only 8% in Syria, where respondents either used a city market or a combination of different markets close to the village.

Across the sites, between 10% and 20% of households surveyed were forced to sell their products at a low price to people within their village, as they were unable to sell them anywhere else. Improving product marketing was therefore one focus of the project.

Adding value and raising incomes

To add value to local products, the project set up food-processing and handicraft units for women. Women were taught how to improve the quality of locally processed foods through the use of better hygiene, packaging, and labeling. Training also covered alternative sources of income, such as growing medicinal plants, herbs, and mushrooms, and developing nurseries. More than 1480 women were trained over five years.

The project also provided women with in-kind incentives such as seedlings (herbs and medicinal plants), containers for locally processed products, and technical and business advice. Products processed by women from a local Women's Union are now being sold in a new 'agrobiodiversity shop' set up near Salaheddin Castle, a major tourist site in Syria. In Palestine, women's groups are now producing and selling honey and shinglish cheese (a dried cheese covered with herbs).

The 278,000 medicinal plant seedlings distributed in Palestine have helped 2240 households become self-sufficient in the medicines derived from them. These households are also selling surplus produce at local markets. Medicinal plants and a new agrobiodiversity nursery are also providing significant incomes for women in Jordan, while in Lebanon women's groups are processing and selling wild plums.

Table 3. Gender-related responsibilities at eight sites in four countries in West Asia (% of households in which a particular group was responsible for the activity).

Activity	Jordan	Lebanon	Palestine	Syria
Collection of edible and medicinal plants				
Women & children	88	100	75	88
Men	12	0	25	12
Preparing food				
Women	98	100	96	100
Men	2	0	4	0
Processing and use of wild plants				
Women	100	100	92	70
Men	0	0	8	30
Sale of medicinal plants				
Women & children	88	60	42	65
Men	12	40	58	35
Seed selection				
Women	75	100	86	10
Men	25	0	14	90
Seed drying				
Women	50	100	60	100
Men	50	0	30	0
Seed storage				
Women	75	100	40	50
Men	25	0	60	50
Seed exchange				
Women	100	-	40	0
Men	0	-	60	100

Alley-cropping with *Atriplex* and cactus: adoption and impacts in North Africa

Unlike agricultural research investments in high-potential areas, the rate of return to research investments in marginal areas is not so clear. Adoption of new technologies in these environments is low because of the variable returns from such technologies, high level of risk, and institutional constraints such as land rights issues. It can be hypothesized that unless public incentives are provided, the potential benefits of new NRM technologies will not be realized. In particular, if the technologies require investments, governments may have to provide subsidies to help establish them. Subsidies are justified if the value of public benefits generated exceeds the amount of the subsidy. The main objective of this research was to assess the uptake and impact of crop/livestock NRM technologies under relevant policy contexts.

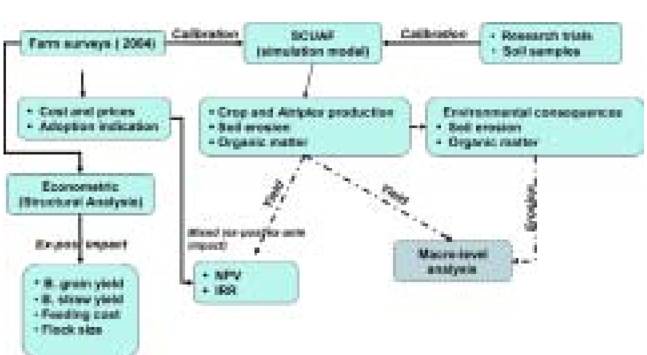
ICARDA's Mashreq and Maghreb (M&M) Project has developed and disseminated many new technologies to farmers and herders in WANA. Successes include improved barley varieties, nutrient-rich feed blocks for sheep, and techniques to boost sheep fertility and restore degraded rangeland. In 2005, researchers assessed the impacts of two alley-cropping technologies already disseminated to farmers: barley with *Atriplex* (saltbush) and barley with spineless cactus. Both cactus and *Atriplex* provide animal feed and can protect the soil.

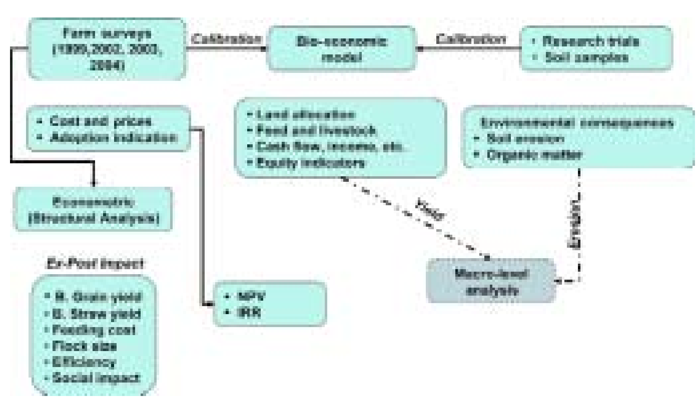
Researchers assessed the impacts of alley-cropping *Atriplex* and barley in Irzain, a community in northeast Morocco. Alley-cropping using cactus was assessed in Zoghmar, in central Tunisia. Both places receive less than 300 mm of rain per year and suffer periodic droughts. Local people rely on a combination of livestock and crop production.

Researchers used econometric models (Figs. 2 and 3) to assess the impact of alley-cropping on barley yields, farmers' use of alternative feed resources, feed costs, and flock size; and also to assess how the provision of a subsidy affected uptake of alley-cropping. Probit, logit, and tobit models were used to determine what factors influenced farmers' decisions to adopt each technology. A range of factors were considered, from the production systems farmers used to policy variables and the areas' natural resources. Community models were also used to assess technology performance at the farm and community levels.

Atriplex alley-cropping in Morocco: adoption and impact

In Morocco, 33% of farmers had adopted the technology on nearly 24% of the land in the community. Researchers found that the area





Source: Adapted and modified after Trewin, 1997. ACIAR Project Workshop, Bogor, 7-8 July 1997, 47 pp.

Fig. 2. Conceptual framework used to assess the impacts of *Atriplex* alley-cropping in Morocco. B = barley; NPV = net present value; IRR = internal rate of return; SCUAF = 'Soil Changes under Agroforestry'.

Fig. 3. Conceptual framework used to assess the impacts of cactus alley-cropping in Tunisia. B = barley; NPV = net present value; IRR = internal rate of return.

under alley-cropping increased as farm size and flock size increased. The net impact of the subsidy provided, according to the model used, was an increase of 79% in the area devoted to *Atriplex*.

Alley cropping with *Atriplex* (above) and spineless cactus provides substantial financial gains to farmers, and greatly reduces soil erosion.

Overall, barley grain and straw yields were 17% and 97% higher, respectively, in the alley-cropping system than in the traditional barley–fallow system. And, because adopting farmers had a more secure feed supply, they increased the size of their flocks by 25% more than non-adopters during the period 2001-2004.

Adopting *Atriplex* alley-cropping also meant that farmers had to buy less feed for their animals—reducing feed costs by 33% on average. Adopters' animals consumed 90% less wheat bran, 36% less barley grain, and 23% less sugar beet, than the animals kept by non-adopting farmers.

Using a mixed *ex-post*/*ex-ante* assessment (Fig. 2), researchers also estimated the internal rate of return (IRR) for the period 1992-2015. This took into account all relevant costs, including research, extension, and the subsidy provided by the development project that promoted the technology. The biomass produced by *Atriplex* was valued in relation to the amount of barley grain that farmers would otherwise have had to buy to feed their animals. Using a discount rate of 10%, the IRR was calculated to be 25%.

Additional 'pessimistic' scenarios were used to calculate alternative IRRs. These scenarios included low *Atriplex* yields due to farmer mismanagement, and low barley grain and straw yields due to bad weather. Another such scenario involved valuing *Atriplex* biomass in relation to the price of barley straw (not grain). However, the IRR estimates were still not less than 18%. This further justifies past investments in *Atriplex* alley-cropping research.

ICARDA researchers interviewing farmers in Morocco on *Atriplex* alley-cropping.

In Morocco, researchers also used the SCUAF (Soil Changes under Agroforestry; Fig. 2) model to assess the environmental impacts of alley-cropping over 15 years. This showed that, in comparison with farmers' usual land-use practices, alley-cropping systems reduced soil loss and greatly improved soil organic carbon levels. Researchers found that the financial benefits of this reduction in soil loss far outweighed the cost of the subsidy provided to farmers who switched to the new system.

Even using very conservative adoption rates of 6%, researchers calculated that alley-cropping could be expanded to cover 350,000 ha in northeast and central Morocco. The potential benefits of this—in terms of higher barley yields and lower feed costs—would be almost US$60 million.

Furthermore, *Atriplex* alley-cropping could be adopted in other Mashreq and Maghreb countries, as they have similar production systems, natural resources, and socio-economic characteristics.

Impacts of alley-cropping using spineless cactus in Tunisia

Just two years after cactus alley-cropping had been introduced, it was being used by 31% of farmers in Zoghmar in Tunisia, on around 30% of the land in the community. Researchers also found, however, that many farmers waited until they received a subsidy before planting cactus. They also showed that in dry years, when cereal yields are low, the cost of this subsidy would be greater than the returns obtained by farmers.

However, it was also found that the availability of cactus as a feed in dry years meant that farmers did not have to sell off as many animals as usual—and so did not lose so many assets. At the farm level, this drop in de-stocking was around 6% on average.

Furthermore, cactus alley-cropping led to a 5% fall in the amount of marginal land cropped in drought years, and so helped to conserve the area's natural resources.

The assessment showed further financial benefits from alley-cropping: farm cashflows rose by 7%, feed costs fell by 13%, and farmers were less dependent on the market for feed. What is more, impacts on the poorest group of farmers were very positive. They no longer fell so far below the poverty line, and their incomes fluctuated less during the year. The technology also increased barley yields, as well as plant cover on eroded lands (because the cactus shelters plants from the wind). This increase in cover led to improved soil organic matter and carbon, phosphorus, and potassium levels, which will help to reduce soil loss through erosion.

Overall, in the two areas studied, the assessments showed that *Atriplex* and cactus alley-cropping could greatly reduce soil erosion, restore soil organic matter, boost crop yields, and provide high returns on farmers' investments.

The development of cactus and *Atriplex* alley-cropping has encouraged public investments in agriculture in the dry areas. This in turn has increased the productive capacity of households' main natural asset, which is land. This will lead to sustainable improvements in the livelihoods of rural communities.

Results clearly show that incentives provided by development projects are important to stimulate technology adoption. Such subsidies can be justified because the internal rates of return are satisfactory if these costs (incentives) are accounted for. In addition, there are environmental benefits. In the case of Morocco, conservative valuation shows that the environmental benefits justify the additional investments that governments are making. The results of this study will help policy makers make decisions leading to investments in productive assets, like drought-resistant shrubs, rather than on feed subsidies.

Mega-Project 6
Knowledge Management and Dissemination for Sustainable Development in Dry Areas

Introduction

ICARDA established a Knowledge Management and Dissemination (KMD) Mega-Project in 2005, in response to concerns about the cost-effectiveness and impact of public investment in pro-poor research. The Mega-Project's primary task is to integrate ICARDA's work on knowledge management and dissemination into its overall research and capacity building agenda. KMD aims to enhance equitable learning, sharing, and access to knowledge in order to contribute to ICARDA's goals of food security, poverty reduction, and the preservation of natural resources.

Specifically, the KMD looks for ways to convert research outputs into national, regional or international public goods (IPGs), that can be scaled up and widely applied to benefit the rural poor. But it is much more than simply an aid to technology transfer. KMD seeks to develop a new paradigm to guide scientists as they benefit from – and build on – local knowledge, to generate demand-driven, feasible, pro-poor knowledge. Thus, KMD is designed as a practical approach that aims to capitalize and add value to ICARDA's past work, and maximize benefits from its future research. Activities include development of TIPOs (Technological, Institutional and Policy Options), individually and in "packages", and provision of training in various disciplines.

The KMD also includes the Seed Unit, which is mandated to assist national programs maintain genetic purity of important varieties, produce high-quality source seed for multiplication programs, provide training, technical backstopping, and promote an informal seed sector, such as community-based seed production, for the benefit of farmers.

Knowledge documentation: the Matrouh Resource Management Project, Egypt

The Matrouh Resource Management Project (MRMP) aims to help control natural resource degradation and alleviate poverty in Egypt's Northwest Coast region. Co-financed by the World Bank, the government of Egypt, and project beneficiaries from 1994 to 2002, the project continues its activities with support from the government of Egypt. Activities include natural resource management (NRM); adaptive research for improvement of crops, rangeland and livestock; and extension, training and social development.

The 20,000 km^2 target area is a semi-desert environment and home to over 20,000 families, mostly *Bedouin*. Agriculture is the main source of livelihood for 80% of project beneficiaries; but only 7% of the total area is cultivated because natural resources are scarce. Rainfall is low and erratic – a mere 145 mm per year on the coast, rapidly declining towards the inland. Crop productivity and diversity are very low, rangeland is degraded. Barley, the principal crop, is integrated with livestock production. Good soils are allocated to figs, olives, mint, and melons. Infrastructure and public services are lacking, economic opportunities are scarce, and the population in this area is among the poorest in the country.

Approaches

The project approaches included decentralized management, community participation, and partnerships between scientists from different disciplines and research and extension staff from multiple institutions. The project area was divided into five sub-regions, and the beneficiaries grouped into 38 Local Communities (LC).

A Matrouh project staff member and a farmer monitor the survival and growth of fodder shrubs.

Community action plans were developed for each community. Each LC elected two committees – one for men, one for women – to facilitate development and implementation of the action plans.

The project produced outputs in five broad areas: new scientific methods/processes/pathways, improved technology for NRM and agricultural production, training and skill development, knowledge dissemination methods, and services and supplies. The impacts were substantial:

- Institutions and communities gained valuable experience in participatory approaches.
- The *Bedouin* community enhanced their knowledge and skills for sustainable NRM and yield improvement.
- Water supply for domestic and agricultural use was doubled
- Over 8 million fodder shrubs were planted, improving fodder production on about 10,000 hectares of rangelands and 2000 hectares of barley area.
- Adoption of TIPOs increased crop yields by about 60%, and reduced the use of expensive feed concentrates.
- Some 58% of beneficiaries increased their income by 25% or more.
- 5000 illiterate girls and women were educated, and 3100 benefited from training.
- 2500 women established small income-generating projects contributing to better nutrition and higher income for the family.
- Communities replaced fuel wood with gas ovens, built latrines, and used manual water pumps.

Analyzing knowledge pathways

The KMD analysis breaks up the project results into various components. What best bet practices were identified? What innovations were developed? What TIPOs were identified, and how were individual TIPOs combined into packages for farmers? How were the packages disseminated?

Best bet practices: adoption of new barley varieties, tree pruning, greenhouse production methods, micro-catchment techniques.

Dissemination methods: a range of methods was used, depending on the target audience. Local communities received information through field days, demonstration plots, LC committees and meetings, and most important, from two institutions established by the project – the Matrouh Adaptive Research Center, and Matrouh Training Center.

The project encouraged *Bedouin* farmers to use supplemental irrigation to grow vegetables and high-value spices, such as mint, shown here, for improved nutrition and income.

Innovations: new management model and participatory community-based R&D approaches, stakeholder integration, integrated watershed management.

TIPOs: a wide range of TIPOs for sustainable NRM, crop-range-livestock improvement, and improvement of women's welfare were developed and disseminated.

Scientists and other partners also exchanged information through annual review and planning meetings, workshops, publications etc. The project has links with many other R&D projects funded by the World Bank, IDRC, IFAD and other donors – another important channel for disseminating the results to development specialists worldwide.

Knowledge documentation: Barani Village Development Project, Pakistan

The Barani Village Development Project (BVDP) aims to reduce poverty in a poor dryland area in Pakistan by improving productivity and conserving natural resources. It is co-financed by IFAD, the government of Pakistan, and project beneficiaries. The first phase (1999-2004) was extended to 2006 on a no-cost basis. ICARDA was responsible for the applied research component in association with six local/national research institutes. Activities covered four broad areas: water and land use management; integrated crop/rangeland/livestock systems; training, capacity building and institutional strengthening; and research management.

The project area consists of six *tehsils* (administrative units) in the *barani* (rainfed) areas of Punjab province, with a total population of 21 million, of whom 83% are classified as rural. Agriculture, their main source of livelihood, is a risky occupation. Rainfall is low and erratic; it declines from 800 mm in the northern parts (with good ground and surface water) to 450 mm in the southern parts, where water resources are limited – and saline. Yields are generally low, with frequent crop failure. Rangelands are often degraded.

There are two cropping seasons, *Rabi* (spring) and *Kharif* (autumn). The major crops are wheat, maize/sorghum, millet, mustard, groundnut, pulses and oilseed crops. Livestock are also important. Most households are poor. The farms are usually too small to provide fully for the family's basic needs – one-third of household income typically comes from off-farm sources.

Approaches and impacts

The project area was divided into three agro-ecological regions: high, medium and low rainfall. An integrated research site with a multidisciplinary, multi-institutional team was established in each zone. A community-based participatory approach was used.

Most of the population in the Barani project area depends on agriculture as the main source of livelihood.

Project outputs targeted different user groups – farm communities, national research and extension agencies, the scientific community, and development agencies. Correspondingly, the outputs covered various aspects: new methods, processes, techniques or pathways; technologies for soil and water management and conservation, improved varieties or parent material, improved production practices, livestock and rangeland development, human resource development, knowledge dissemination methods, and services.

The impacts include:

- Research institutions, NGOs, and farming communities gained experience in multi-institutional collaboration and participatory approaches to R&D.
- The concept of integrated research sites has been established as a tool for community-based R&D, and is being extended to other areas (Balochistan).
- Mechanisms and an enabling environment have been developed for up-scaling technologies validated by the project.
- Water supply and management have improved, soil erosion controlled.
- Crop and livestock productivity have increased substantially, but adoption and impact has not yet been analyzed.
- Micro-enterprises have been initiated for producing urea-molasses feed blocks and quality seed.
- Together, these results have formed the basis of an overall effort to improve livelihoods.

Analyzing knowledge pathways

The KMD analysis in Pakistan looked at various project components and related outputs.

- *Best bet practices*: integrating research and development at project sites, cost-effective water outlets and control structures, new crop and animal germplasm, use of feed blocks and urea-molasses to supplement feeds of small ruminants.
- *Innovations*: community participation and stakeholder integration process, cost-effective water outlets and erosion structures.
- *TIPO packages:* a wide range of individual TIPOs was developed for improved but sustainable management of crops, livestock, range and other natural resources. Some technologies were combined into packages suited to *barani* areas.
- *Dissemination methods*: publications, workshops, conferences, TV and radio, demonstration plots. A large number of documents on planning, design, implementation, monitoring and evaluation of project activities are available at the Agency for Barani Area Development, and at ICARDA and partner institutes. The project also has links to many other R&D projects, facilitating global exchange of information on dryland area development.

Cost-effective, simple water-regulating structures were designed by the project and implemented by farmers, for erosion control and rainwater management.

International seed trade conference

The WANA region imports seed of various crops worth over $250 million. But few private seed companies are taking advantage of this huge market potential within the region and beyond. National seed industries focus on domestic markets, with little or no seed trade among countries. Moreover, trade is restricted by both tariff and non-tariff barriers – policy, regulatory, institutional, and technical constraints.

ICARDA worked with the Turkish Seed Industry Association to organize an international seed trade conference in Antalya, Turkey, to stimulate regional contacts and encourage private sector seed trade. Specifically, the conference aimed to:

- Review the potential of seed markets in the CWANA region
- Provide a forum to promote business contacts among seed companies
- Provide opportunities for stimulating regional seed trade
- Share experiences among stakeholders in the seed trade
- Explore opportunities for a regional seed trade association.

The conference attracted more than 225 participants from 45 countries, representing private firms from the CWANA region, private seed and agricultural input suppliers from Africa, Asia, Europe and USA, private seed

CWANA international seed trade conference in progress in Antalya, Turkey.

equipment manufacturers from Asia, Europe and USA; international/regional/national private sector seed trade associations from Asia and Europe; and international/regional development organizations working on seed issues (ISF, ISTA, OECD, UPOV, CIHEAM, ICARDA).

Promoting contacts and seed trade was a key element of the conference. There were 33 exhibitors: public and private seed companies, input suppliers, and manufacturers of seed equipment and agricultural machinery. A trading floor was set aside for potential customers and suppliers, and did excellent business.

The presentations and panel discussions covered a range of policy, regulatory, institutional and technical issues affecting the seed industry. Several sideline meetings were also held with public seed agencies and private firms. The most important outcome was an agreement to establish a Regional Seed Association for Central and West Asia, and to hold an international seed trade conference every alternate year. Building on these discussions, ICARDA is now exploring options to devolve some of its seed activities to regional players, for example by transforming the WANA Seed Network into a Regional Seed Association.

Lessons learned from seed aid interventions in Afghanistan

ICARDA is implementing an IDRC-supported project on "Strengthening seed systems for food security in Afghanistan." The project aims to provide a deeper understanding of how local seed systems in Afghanistan adapt to stress and conflict conditions; and use this understanding to identify how to strengthen seed aid interventions and farmers' crop production systems. Extensive consultations with stakeholders in 2004 and 2005 helped document institutional and social aspects of the informal seed system, issues emerging from the return of displaced populations, and the benefits of emergency seed relief.

The study suggests that almost all branches of the formal seed system are weak – research, variety maintenance, seed multiplication and dissemination, extension services. The informal system has proven resilient to conflicts and drought; but it too has a number of shortcomings: weak local institutions, over-exploitation of the same crop varieties, inadequate introduction of new genetic materials, and inequity in seed access between relatively well-off and poor farmers, and between men and women. Seed quality is generally sub-optimal because of poor production and processing technologies, and the formal system is unable to provide quality control services for locally produced or imported seeds. In all communities, well-known "nodal" farmers produce and supply seed to other farmers, on credit or for payment in cash or kind. Some farmers have seed stocks of a large number of varieties (partly because they grow different varieties to spread risk), but lack the skills to produce quality seeds for other farmers.

One project component looked specifically at the problems of women farmers. Widows can inherit land, but it is usually rented out to other males, for cash or sharecropping. In male-headed households, women must work under male supervision, except for small vegetable plots and kitchen gardens. Because of social restrictions on the movement of

An assessment of seed aid interventions in Afghanistan.

women, it is mainly the men who have access to new agricultural technologies including seed and extension services. Clearly, it is important to make more efforts to target women. But opinions are divided as to how best this can be done; for example, whether it is practical to distribute seed directly to women.

Emergency seed interventions in 2002-03 had a generally positive impact. In the majority of communities studied, farmers reported that production had increased by up to 40% as a result of planting improved seed received from aid agencies. Most NGOs also supported these views although they did not carry out systematic impact assessments. The major concern, however, was that not all farmers received seed aid; and those who did, received only small quantities. Development programs feel concerned that these efforts do not encourage self-reliance; farmers have begun to expect continuing (and increasing) free seed distribution; and the program is discouraging private seed enterprises.

The assessment also examined the role of social networks and institutions. It was found that the village councils (predominantly male) played a key role. The councils maintain community regulations and traditional laws, and resolve conflicts within the community. Correspondingly, they played an important role in enforcement of the "code of conduct", seed aid distribution, and inception of new projects.

Seed relief interventions, being short term, did not enhance social networks between farmers, their organizations, and seed vendors, which in many cases were nonexistent. Nor did they strengthen local seed system capacity. In terms of "village politics", many communities who received seed aid stated that the authority and influence of the village council had increased as a result. But overall, the time frame was too short to expect substantive social and institutional changes.

There is still a compelling need to improve food security and livelihoods in Afghanistan. Seed as well as other interventions will be required. There seems to be only limited justification for continuing large-scale emergency seed relief; it is more important to focus on long-term seed system development.

In view of the weakness of the formal seed system and the importance of the informal system, perhaps the solution is to strengthen local or community-level seed systems. ICARDA and FAO are taking the lead in establishing viable small-scale seed enterprises in some provinces. This emerging private sector will require support and incentives, particularly in areas of acute or chronic seed insecurity.

In the medium term, institutional and capacity building (for both formal and informal systems), implementation of recently enacted seed laws (regulatory reforms), and improving the policy environment will all be necessary. Also necessary will be research on some key areas: land tenure, labor migration, and the dynamics of household decision-making on access and use of resources as well as income generation and spending.

Village-based seed enterprises in Afghanistan

ICARDA's Seed Unit has established 20 Village-Based Seed Enterprises (VBSEs) in Afghanistan as part of a USAID-funded program known as RAMP (Rebuilding Agricultural Market Program). The aim of the program is to improve farmers' access to quality seed of a wide range of local and improved varieties; and equally important, to ensure that VBSEs are economically viable. It is expected that at least half the 20 VBSEs will be making profits before the program ends in 2006.

The rationale is that market-oriented VBSEs will accelerate the process of farmer-to-farmer diffusion of improved varieties; improving crop productivity and farm incomes, and also maintaining agrobiodiversity.

Substantial quantities of seed have been produced and sold, to farmers and organizations involved in agricultural reconstruction. Seed production has increased four-fold compared to the 2003/04 cropping season. This year, 17 VBSEs produced 2188 tons of wheat seed, 651 tons of rice seed, 429 tons of mung bean seed, and 887 tons of potato tubers. On average, each VBSE produced over 100 tons of wheat seed – meeting the end-of-project target one year earlier.

Wheat produced by a Village-Based Seed Enterprise group of farmers in Afghanistan.

Profitability figures are equally encouraging, largely because of very high demand for seed. In the 2004/05 cropping season, field-level production costs averaged $129 per ton for wheat seed; estimated post-harvest processing and marketing cost was $45 per ton. VBSE members received prices ranging from $285 to $420 per ton, i.e. profits of $111 to $246 per ton. All VBSEs did not benefit equally from high prices; margins depended on negotiation skills, sales timing, volumes, and quality (seed processing, quality certification). The most progressive VBSEs are not only cashing in on the seed market but also diversifying into other crops. One-third of the VBSEs produced onions and tomatoes – 632 and 1438 tons, respectively. About 30% of the tomato harvest was processed to make tomato seed.

The VBSEs achieved record returns this year because of high prices for wheat seed; but not all enterprises have the financial management skills needed to ensure sustainability over time. ICARDA will continue to provide technical support in many areas: quality control, finance and business management, and marketing.

International Cooperation

ICARDA collaborates with NARS, donors, and advanced research institutions worldwide, on agricultural research and training. This section outlines NARS-ICARDA partnership-building activities (meetings, capacity building, and other initiatives). Appendices 4, 5, and 6 provide a complete list of collaborative projects and networks; while research results are reported in the section on Mega-Projects.

ICARDA's research portfolio covers a wide spectrum of activities, from strategic to adaptive research to technology transfer. The Center promotes partnership with NARS through six Regional Programs across the CWANA region: North Africa, Nile Valley and Red Sea, West Asia, Arabian Peninsula, Central Asia and the Caucasus, and Latin America. Problems of agriculture in high-elevation areas are addressed through a Highland Research Regional Network.

Regional Programs.

North Africa Regional Program

The North Africa Regional Program (NARP) coordinates activities in Algeria, Libya, Mauritania, Morocco and Tunisia, and is administered through ICARDA's regional office in Tunisia. Some NARP activities cut across into West Asia. The objectives are to contribute to poverty alleviation, natural resources conservation, enhancement of crop and livestock productivity, diversification of production systems and incomes, human resources and capacity building, and networking.

Collaborative projects

Seven collaborative projects were implemented during the year:

- SDC Maghreb: Sustainable management of the agro-pastoral resource base in the Maghreb, Phase II. Funded by SDC. Algeria, Libya, Mauritania, Morocco, Tunisia
- IRDEN: Regional program to foster wider adoption of low-cost durum technologies. Funded by IFAD. Algeria, Morocco, Syria, Tunisia, Turkey
- SDC-Mountains Maghreb
- Scarce water in WANA
- Assessing the potential of water harvesting and supplemental irrigation in WANA
- Mashreq and Maghreb (M&M) Project, Phase III: Developing sustainable livelihoods for

A pioneer on-farm seed producer (right) from Jemaat community, inspecting fields of new durum wheat varieties with INRA researchers in Morocco.

agro-pastoral communities of West Asia and North Africa. Funded by IFAD and AFESD. Iraq, Jordan, Lebanon, Syria in the Mashreq region; and Algeria, Libya, Morocco, and Tunisia in the Maghreb region
- Livestock health and market opportunities. Funded by IFAD, implemented in collaboration with ILRI.

There are also bilateral and multilateral projects in various countries, described below.

Five projects were implemented in **Tunisia**, four of them with funding from USDA: Medicinal plants in Tunisia, in collaboration with IRA Medenine; Small ruminants Phase II, with ILRI; GIS for watershed management in the arid regions of Tunisia Phase II; and an Oat and vetch project. A fifth project, on biological control of weeds, is being managed by ICARDA.

These projects have enhanced ICARDA's partnerships with research and teaching institutions in Tunisia (IRESA, INRAT, INAT, IRA Medenine) and beyond. Collaborators include the USDA Agricultural Research Services and several American universities: University of Minnesota, Purdue State University, Fort Valley State University – Georgia, and University of Mississippi.

In **Mauritania**, a bilateral project entitled "Rapid impact program on research and extension" entered its third year. Project staff worked with two rural communities in Brakna Province to identify constraints and opportunities, and negotiated an action plan for technology transfer in each community. Field activities in 2004/05 covered livestock nutrition and health, water harvesting, introduction of cactus planting, seed treatment and storage, livelihoods characterization, and analysis of poverty profiles in the two communities. Plantations of spineless cactus were established at two research stations and in farmers'gardens. Technicians from research institutions and development projects were trained on cactus production and utilization as livestock feed. Eight NARS managers were trained in English language skills. Staff at several research institutions (DRFV, CNRADA, CNERV, and ENFVA) were provided training in communication and computing.

ICARDA also backstopped the AfDB-funded PADEL project on rangeland management and improvement of livestock in Mauritania. The work focused on participatory and community approaches, water harvesting, alternative feed resources, and rangeland management. Researchers helped test a "pastoral code" in a pilot zone in Kiffa, where the community developed and implemented rules for managing common resources.

In **Morocco**, INRA-Morocco and ICARDA began implementing a grants program, under which five new short-term projects were launched during 2004/05 on barley improvement, durum wheat improvement, genetic resources and genebank management, IPM in cereal-legume systems, and INRM and conservation agriculture. The results were encouraging. In addition, INRA, ICARDA and ARS/USDA began a two-year project on medicinal plants.

Backstopping IFAD development projects in North Africa

ICARDA backstopped a major IFAD development project in North Africa, providing technical support for rural development in the mountains of Eastern Morocco (Taourirt Taforalt). Activities included sociology, local institutions, and rangeland management research, promotion and marketing of mountain products, impact assessment, and a traveling workshop for research technicians. In addition, the M&M team in Tunisia, in collaboration with IFPRI, conducted field research on the empowerment of agropastoral communities in the Tataouine region.

Workshops and coordination meetings

The North Africa Regional Program organized a number of workshops and training programs. These included regional and international workshops on INRM, wheat technologies and rural development, training workshops on livestock and range management, regional planning meetings, as well as national coordination meetings in Algeria, Libya, Morocco and Tunisia to review research results and develop work plans for the next year. These meetings attracted a large number of national scientists, and helped develop several research proposals for submission to potential donors.

Nile Valley and Red Sea Regional Program

The Nile Valley and Red Sea Regional Program (NVRSRP) covers Egypt, Eritrea, Ethiopia, Sudan, and Yemen and operates through ICARDA's regional office in Cairo. The overall objective of NVRSRP is to increase the income of smallholder farmers in the region by improving productivity and sustainability of production systems, conserving natural resources, and helping to build national research capacity.

Collaborative projects

Several collaborative projects were in operation during the year:

- Egypt: Improvement of food legumes and cereal crops; Natural resources management project; Control of wild oats in cereals and other winter crops; Barley participatory breeding in Marsa Matrouh
- Ethiopia: Strengthening client-oriented research and technology dissemination for sustainable production of cool-season food and forage legumes
- Sudan and Ethiopia: Transfer of improved production packages for wheat and legumes
- ICARDA/AGERI project on identifying resistance genes to abiotic stresses in cereals and transformation in food legumes
- ICARDA/CLAES project on upgrading faba bean and wheat expert systems
- Technology generation and dissemination for sustainable production of cereals and cool-season legumes in the Nile Valley countries. Funded by IFAD.
- Eritrea: Integrated cereals diseases management (ICDM) project; Water and Food Challenge Program
- Community-based optimization of the management of scarce water resources in agriculture in WANA: a new project funded by AFESD and IFAD, in all NVRS countries. A benchmark site on irrigated agriculture was established in Egypt, with satellite sites in Sudan and Iraq.

A series of traveling workshops in Sudan, Egypt and Yemen attracted over 300 scientists, farmers and extension staff. Participants visited on-station and on-farm trials, demonstration plots, and farmer field schools; and discussed the performance of a range of technology packages for wheat, faba bean and chickpea, as well as seed production schemes.

Participants of the 15th Coordination Meeting of the Nile Valley and Red Sea Regional Program, held at ICARDA.

Workshops and coordination meetings

ICARDA and its partners organized several workshops on horticulture, plant genetic resources, post-conflict rehabilitation of agriculture, as well as national coordination meetings in Ethiopia, Eritrea, Egypt, Yemen and Sudan, and the annual steering committee meeting for the regional program. A large number of national scientists participated.

Partners in these efforts included the World Vegetable Center, University of California at Davis, FAO, CGIAR Centers, and NARS.

Human resource development

Several training courses were conducted in 2005 to improve the skills of researchers and enhance regional cooperation. These were short courses tailored to meet specific NARS needs in various areas – farmer-participatory research methods, impact assessment, community seed production, greenhouse management, expert systems, small ruminant production and health, molecular markers, design and analysis of field experiments, weed management, electronic publishing, and publications assessment methods.

Regional traveling workshop in Egypt. Farmers, researchers and extension personnel from Egypt, Ethiopia, Sudan and Yemen participated.

The training courses attracted over 150 researchers from 12 countries – Afghanistan, Algeria, Egypt, Ethiopia, Iran, Kenya, Jordan, Morocco, Sudan, Syria, Tunisia, and Yemen.

Technical assistance

During 2005, ICARDA provided technical assistance to NARS partners in the sub-region.

- Support to the Matrouh Resource Management Project in Egypt: ICARDA staff visited the project to help select barley lines adapted to local conditions and design and plant trials and nurseries. Another ICARDA team helped investigate the impact and sustainability of project outputs.
- ICARDA pathologists conducted a survey of rust diseases on wheat and barley crops in Eritrea and Yemen.
- In Eritrea ICARDA scientists worked with the National Institute of Agricultural Research to conduct the country's first survey on virus diseases of chickpea, supported by the Canada Fund for Africa. The field survey was followed by laboratory analysis; 6400 samples from 31 chickpea fields were collected and tested serologically against nine viruses. Five Eritrean research assistants participated in the survey, and received extensive training in survey and analytical methods.

New grass pea variety released

The Ethiopian Agricultural Research Organization (EARO) announced the release of a grass pea variety 'Wasie', derived from ICARDA germplasm. This is the country's first low-neurotoxin variety of grass pea safe for human consumption. The new variety has broken the fear of paralysis among Ethiopians.

West Asia Regional Program

The West Asia Regional Program (WARP) promotes regional cooperation in research, capacity building and information dissemination in Cyprus, Iraq, Jordan, Lebanon, Palestine, Syria and the lowlands of Turkey. WARP, which operates from ICARDA's regional office in Amman, Jordan, continued to provide germplasm nurseries, technical support, and training to all countries in the region, including Iraq and Palestine, despite difficult political conditions. Several promising lines of barley, bread wheat, durum wheat, lentil, chickpea, and vetch were selected by national programs, and are awaiting release. In addition, more than 13 regional or bilateral projects were implemented in collaboration with NARS.

WARP organized several coordination and steering committee meetings to monitor and plan for ongoing projects and develop new initiatives (e.g. Phase III of the M&M project). An FAO/ICARDA workshop on plant genetic resources attracted delegates from 14 countries in West Asia and the Arabian Peninsula. From November 2005, the WARP office in Amman became the host of the secretariat of AARINENA, the umbrella body for coordination of agricultural research in the region.

In Jordan, in recognition of ICARDA's efforts, His Majesty King Abdallah II awarded the Center's Director General, Prof. Dr Adel El-Beltagy, the Al-Istiklal medal, the highest honor in the country. ICARDA also won three other awards from the University of Jordan and the National Center for Agricultural Research and Technology Transfer (NCARTT) in recognition of its contributions to promoting agriculture in Jordan and the West Asia region.

New Memorandums of Understanding (MOUs) were signed with the University of Jordan and the Jordan University for Science and Technology. Another MOU was drafted between ICARDA and the Higher Council for Science and Technology to enhance collaboration with the Badia Research and Development Centre. Four field days, organized by the dryland agrobiodiversity and water harvesting projects, helped promote technologies to rehabilitate degraded rangelands in the Badia. The participatory barley breeding program at NCARTT was extended to include wheat and food legumes.

Collaboration with Iraq is being expanded, in response to requests from the Ministry of Agriculture. These requests, expressed at a series of donor meetings, involve support for various projects aimed at rehabilitating agriculture in the country. ICARDA has succeeded in securing funds from Australia to increase production of field crops in Iraq.

Similarly, in Palestine, the Ministry of Agriculture has requested ICARDA's assistance to rehabilitate agriculture and specifically to reorganize activities at the National Agricultural Research Center. An MOU was signed between ICARDA and the UNDP for joint development efforts in Palestine.

Iraqi delegation with researchers from Australia and ICARDA during their visit to ICARDA for the Iraq project planning meeting in September 2005.

West Asia Dryland Agrobiodiversity project

The West Asia Dryland Agrobiodiversity (WADA) project concluded in 2005. This 6-year project helped develop and promote strategies for *in situ* (on-farm) conservation of agrobiodiversity in dryland areas in the region. In its final year, activities focused on documentation and dissemination of technologies generated, and preparation of "exit strategies" that would ensure sustainability of conservation activities.

Several reports and databases were produced: documentation of local agrobiodiversity (and major threats) in different areas, drafts of national agrobiodiversity policies and legislation, community development plans and natural habitats management plans at pilot sites, and field guides for the identification of *Lathyrus* and *Medicago* species.

The project succeeded in introducing biodiversity conservation in school curricula in Palestine and Syria and in establishing an MSc program on biodiversity conservation at the Jordan University of Science and Technology.

In April 2005, ICARDA organized the first international dryland agrobiodiversity conference in Aleppo, attended by 152 participants from 21 countries. ICARDA organized a ministerial meeting in Amman in June 2005, attended by the Ministers of Agriculture of Jordan, Lebanon, Palestine and Syria, as well as representatives from UNDP, ACSAD, IPGRI and AOAD. The four countries signed an MOU to promote agrobiodiversity conservation and exchange of genetic resources.

The final project evaluation was presented at an end-of-project meeting in Amman. Targets were met or exceeded. There is already evidence of impact on capacity building, public awareness, and institutional changes, but impact on agrobiodiversity will become measurable only in the longer term. All NARS representatives in the project steering committee – and participants at the international agrobiodiversity conference – acknowledged the achievements of the project. They recommended that, rather than being concluded, efforts should be extended to other countries in the CWANA region. A draft concept note has been prepared for a new project focusing on knowledge sharing and dissemination aspects, for possible GEF funding.

Arabian Peninsula Regional Program

The Arabian Peninsula Regional Program covers seven countries: Bahrain, United Arab Emirates (UAE), Kuwait, Oman, Qatar, Saudi Arabia and Yemen. The administrative office is located in Dubai, UAE. Activities include on-farm water management, irrigated forage and rangeland management, and high intensity production system (protected agriculture). The emphasis is on strengthening national institutions, enhancing human resource capacity, technology development and transfer, and promoting information technology and networking. The program is funded by AFESD, IFAD, and the OPEC Fund.

Indigenous forage crops grown with minimum water in farmers' fields in the United Arab Emirates.

A farmer in Yemen produces high quality cucumbers using IPPM.

Cactus management training at Rumais Station, Sultanate of Oman.

Participants in the training course on molecular markers for fingerprinting date palm varieties in the United Arab Emirates.

Collaborative research

Soilless culture is an intensive production system for the production of high-quality cash crops. NARS-ICARDA teams are implementing on-farm trials to transfer this technology to private growers. In Oman, farmers who lost production due to salinity, are now using soilless culture introduced by ICARDA. In Kuwait, soilless culture has increased production significantly and reduced water use by over 50%. In Yemen, adoption of integrated production and protection management (IPPM) practices for the production of cucumber in greenhouses has reduced pesticide use and increased irrigation efficiency by up to 93%.

Large areas of the Arabian Peninsula are desertified, primarily because of overgrazing. In order to cope with feed shortages, farmers produce forage crops using underground water for irrigation. This is threatening water resources in the region. The regional program is promoting the use of indigenous forage species to provide livestock feed and rehabilitate degraded rangelands. Indigenous plant species were found to be of high value as forage crops; their water-use efficiency is high, a feature that is extremely useful in dry areas. Buffel grass or leybid (*Cenchrus ciliaris*), which proved to be a good forage, has been introduced to a number of private farmers in the UAE.

Thirty-eight accessions of spineless cactus were introduced by APRP at the Rumais Research Station in Oman, and they are now well established. These will be distributed to partner NARS through the Sultanate.

New partnerships

ICARDA and the NARS in the subregion have drafted a joint proposal for a large-scale technology transfer project for the Arabian Peninsula. Other partnerships continue to develop. ICARDA and the University of Sana'a, Yemen, signed an MOU in early 2005, to promote research in intensive production systems, conserve natural resources, and improve information technology. Another MOU was signed in mid 2005 with the Kingdom of Saudi Arabia for the establishment of a seed technology unit. ICARDA provided equipment, training and technical support for the unit, which was established to enhance the production of seed of native forage and range plants in northern Saudi Arabia.

Workshops and coordination meetings

Two end-of-project meetings were held in December 2005 in Muscat, attended by 52 participants from the seven partner countries as well as FAO and the Netherlands. The meetings were hosted by the Ministry of Agriculture and Fisheries. They discussed, among other issues, a new project proposal to transfer successful technology packages developed during the current project.

Two recently launched projects held their first coordination/management meetings. The project on development of sustainable date palm production systems in the GCC countries met in Aleppo in May 2005.

Twenty-nine participants from the various partner NARS discussed research priorities and the first season's work plans. Similarly, the project on protected agriculture in Yemen held its first steering committee meting at ICARDA's regional office in Taez, in June 2005. It was attended by representatives of two government ministries – Agriculture and Irrigation, and Planning and Development – and from the French embassy.

Human resource development

Several training programs were organized, covering various aspects: development of project proposals, scientific writing and data presentation, soilless culture, greenhouse installation and management, propagation and management of forage (spineless) cactus, and molecular markers for fingerprinting of date palm. A total of 80 people participated: researchers, extension staff, NGO field staff, and farmers from across the Peninsula.

Highland Research Regional Network

Highlands (> 800 masl) cover over 40% of the agricultural land in CWANA, and are home to the most disadvantaged section of the population in the region. The harsh environment and poor accessibility, to a great extent, explain the neglect of these areas by national and international research and development organizations. Harsh conditions promote outmigration and land abandonment. Subsistence is secured from drought-tolerant, low-productivity crops such as barley, as well as fruit trees and vegetables, and from transhumant flocks of small ruminants that move to mountain pastures in the summer. Much of the agriculture is conducted on sloping land and soil erosion is a major problem, especially in areas that have become degraded as a result of overgrazing and other inappropriate farming practices.

From its early days and until mid-2004, ICARDA managed its regional highland activities through the Highland Regional Program, that included countries of North Africa, West Asia, and CAC. Because those countries fall within the geographic mandate of other ICARDA Regional Programs, it was decided to address the problems of highland agriculture within the framework of a Highland Research Regional Network (HRN). The goal of HRN is to contribute to improving the welfare of rural populations in the highlands of CWANA through strategies and technologies for sustainable improvement of agricultural productivity in these areas. ICARDA project staff are located in Iran and Afghanistan, while work in Turkey is handled from the Center's headquarters.

A cereal field of the Village-Based Seed Enterprise participants in Kunduz province, Afghanistan.

Afghanistan

ICARDA manages its highland collaborative research program in Afghanistan through a central office in Kabul, which coordinates the work in six target provinces – Ghazni, Helmand, Kabul, Kunduz, Nangarhar and Parwan. The office coordinates the activities of the Future Harvest Consortium to Rebuild Agriculture in Afghanistan. It also provides technical and logistic support to the DFID-funded program on research on alternative livelihood (RALF).

Collaborative research

ICARDA works with the Ministry of Agriculture, Animal Husbandry and Food (MAAHF) and national

H.E. Mohamed Sharif, Deputy Minister of Agriculture, discusses the importance of RALF field research trials with farmers, faculty members and project staff at the research farm of the University of Nangarhar, Afghanistan.

research institutes to rebuild agriculture in Afghanistan, through the USAID- and ICARDA-funded Rebuilding Agricultural Markets Program (RAMP). This consists of four projects: demonstrations and promotion of new technologies, village-based seed production, protected-agriculture systems for cash crop production, and production and marketing of seed potato (a joint project with the International Potato Center, CIP).

ICARDA established 356 demonstration plots for nine crops – wheat, potato, onion, tomato, rice, mung bean, cotton, okra and groundnut – in five target provinces of Ghazni, Helmand, Kunduz, Nangarhar and Parwan. The introduced crop varieties and associated technologies have significantly out-yielded local varieties in farmers' fields.

To facilitate adoption, ICARDA established 21 village-based seed enterprises (VBSEs) to produce and disseminate quality seed of improved varieties adapted to local conditions. The Center provided technical assistance in seed production, trained farmers on how to run a profitable seed business, and provided agricultural machinery and source seed. To date, the VBSEs have produced over 2000 tons of cereal seeds. Seed is processed and marketed to the community and to international agencies.

Scientists from ICARDA and MAAHF continue to work on protected-agriculture technology for marginal, water-deficit areas. In addition to the earlier established Protected Agriculture Center comprising four greenhouses and a greenhouse-manufacturing workshop, 42 greenhouses have been installed on farmers' fields and in MAAHF premises. Farmers, extension workers, NGO personnel and MAAHF staff were trained on the installation and maintenance of greenhouses for growing cash crops like cucumber, tomato, lettuce and green pepper. Adoption is growing rapidly – some 200 farmers have requested greenhouses at subsidized prices or on credit.

Potato is one of the staple crops in Afghanistan. In collaboration with CIP, ICARDA has conducted research on the production, multiplication and marketing of clean potato seed to reduce the current dependency on imports. Seed producer groups in five target provinces have produced and marketed over 1500 tons of high quality clean seed potato of improved varieties. Facilities for micro-propagation have been established and used for the multiplication of improved varieties. The 15 country stores earlier constructed have been successfully used to store 70 tons of potato seed, and 18 new country stores were constructed in Ghazni, Helmand, Nangarhar, Parwan, and Bamyan.

A tissue culture laboratory was established and Afghan technicians were trained in micro-propagation and mini tuber production techniques. Four improved varieties – Kufri Chandarmukhi, Desiree, K. Badshah, K. Phukraj – were cultured *in vitro* to produce basic seed.

ICARDA scientists, through two RALF-funded projects, have identified viable alternatives to reduce the dependency of Afghan farmers on opium production. One such alternative is dairy production. Among other activities, the project is examining the possibility of growing high-yielding and nutritious forage legumes in north-eastern Afghanistan, to increase milk production.

The other project focuses on mint, and operates in Helmand, Kunduz and Nangarhar. Research/demonstration plots have been established, field days organized, and a mint producers association established. The project aims to transform mint from a kitchen garden herb to a commercial crop by promoting large-scale production and marketing, e.g. for culinary as well as medicinal uses.

New projects

Two new research projects were developed and submitted to donors – one on training programs for capacity building, and the other for diversifying farmers' livelihood opportunities in eastern Afghanistan, through improved technologies and better seed availability.

Workshops and coordination meetings

ICARDA organized a number of meetings in Afghanistan, to plan and monitor two major collaborative projects: the Future Harvest Consortium and the DFID-funded RALF program, which comprises 11 sub-projects. Participants included scientists and administrators from Afghanistan, international agencies (USAID, FAO, JICA, DAI, CIAT), and NGOs; the Ministry of Counter-Narcotics, Ministry of Commerce, four Afghan universities, as well as educational, research and industrial organizations from Iran and Pakistan.

Capacity building

Over 30 training courses were organized: in-country training for technicians, intensive 1- or 2-week courses for research staff, and a range of training programs for farmers and extension/NGO staff in several provinces, using a combination of practical training, field days and farmer field schools. In all, some 4700 people participated, including over 3500 farmers. The topics covered included: protected agriculture and hydroponics, installation and maintenance of greenhouses, manufacturing of greenhouse components, crop production and protection techniques for field crops, cash crops production in greenhouses, seed health testing, variety identification, seed certification, processing and storage, management and profitability assessment of village-based seed enterprises, production and marketing of seed potatoes, tissue culture, and survey methodologies.

Integrated crop and disease management training in Afghanistan. Trainees and trainers are from Parwan province.

Turkey

Turkey formally became a CGIAR member in 2005. ICARDA has worked with the Turkish NARS for several years, through bilateral projects. ICARDA is collaborating with Turkey in four major bilateral projects: improvement of winter facultative wheat, promotion of winter-sown lentil, promotion of low-cost durum technologies (IRDEN), and use of naturally occurring fungi to control the Sunn pest.

Under the joint Turkey/CIMMYT/ICARDA International Winter Wheat Improvement Program, germplasm was developed and tested in Turkey and Syria and then distributed to other parts of CWANA. Three hundred sets of international nurseries of winter facultative wheat were sent to 50 NARS partners for testing and selection. International nurseries (18 winter facultative wheat, 5 durum wheat, 2 spring bread wheat, 3 barley, 12 lentil, 15 chickpea, 2 faba bean and 6 forage legumes) were provided to Turkish partners for testing at research institutes and universities in various regions.

Under the GAP/ICARDA project, 20 tons of seed of lentil variety Idlib-3 (released in Syria) was planted in the 2004/05 season by farmers in the South East Anatolia Region. Another 170 tons was planted on 1700 ha in the 2005/06 cropping season.

Capacity building and collabora-

Scientists from Turkey visit the winter and facultative wheat breeding trials at ICARDA, May 2005.

tion through training programs, meetings and workshops was a major activity in 2005. Turkey and ICARDA jointly organized three meetings in Turkey on the CWANA international seed trade; International Assessment of Agricultural Science and Technology (IAASTD)-CWANA sub-global assessment authors' meeting; and land races. Fifteen Turkish scientists attended several meetings and workshops at ICARDA on wheat, water productivity, seed policy, and Sunn pest control.

Turkey, CIMMYT and ICARDA organized an international training course on conservation agriculture technologies for rainfed wheat production systems in Turkey, attended by 24 researchers from 13 CWANA countries. Seven Turkish scientists visited ICARDA for 1–2 weeks for courses on seed production, DNA molecular marker techniques, and electronic production of documents and web databases. Another 13 Turkish scientists visited the Integrated Gene Management Program to get acquainted with cereals and legumes research at ICARDA and interact with the scientists. Also, seven ICARDA scientists visited Turkey to provide technical assistance and monitor collaborative activities.

Iran

Iran is now self-sufficient in wheat production. Production was adequate for the second year running, after four decades of deficits, and is expected to increase to a surplus next season. ICARDA has played a significant role. Twelve years of collaboration between DARI and ICARDA has led to the release of several new varieties of food, feed and oilseed crops, as well as improved soil and crop management practices that have significantly contributed to increased yields.

More than 485 collaborative projects and trials were conducted in Iran during the 2004/05 season: variety testing, long-term crop rotations, supplemental irrigation, water harvesting, soil management, and crop management. Five durum, six bread wheat, and five barley varieties were selected for different environments. Two legume varieties – chickpea FLIP 93-93 and lentil FLIP 92-12L – are expected to be released for commercial cultivation. Forage lines from *Vicia panonica* and *V. dasycarpa* (for cold regions), and colza hybrid Hyola 308 (for warm regions) are candidates for release. The colza line PI 537598 was recommended for seed multiplication. Future impact is expected to be even greater: the Ministry of Agriculture-e-Jihad plans on-farm demonstration trials on about 500,000 ha across five provinces.

A new project was launched with SPII for spring wheat improvement in irrigated areas in the lowlands of Iran, with possibilities of expansion to similar environments elsewhere in CWANA. Many lines and parental germplasm have been selected and the crosses made. SPII, ICARDA and CIMMYT are now discussing the possibility of a similar project on winter and facultative wheat.

The Karkheh River Basin projects on water productivity and livelihoods resilience are well under way. Baseline surveys have been completed, pilot communities and sites have been selected. More than 25 proposals will be implemented, focusing on improvement of livelihoods, watershed management and water-use efficiency.

Central Asia and the Caucasus Regional Program

Established in 1998, the Central Asia and the Caucasus (CAC) Regional Program is the youngest outreach program of ICARDA. It covers eight countries: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan in Central Asia; and Armenia, Azerbaijan and Georgia in the Caucasus. The Program has built strong partnerships with the NARS in germplasm improvement, plant genetic resources, soil and water management, integrated feed and livestock production, and human resource development.

A Field Day in Tajikistan: demonstration of improved chickpea and lentil lines selected from ICARDA-supplied genetic materials. About 65 farmers attended the event.

New technologies

Three new varieties were released in 2005. Almira, a bread wheat variety, was released in Kyrgyzstan; chickpea variety Narmin and *Lathyrus* variety Ali Bar were released in Azerbaijan and Kazakhstan, respectively. About 50 promising varieties are now being tested for final release in different countries. The major emphasis is on on-farm testing of improved varieties and seed production of released varieties, to stimulate large-scale adoption.

Genetic resources

Genetic resource conservation efforts have been strengthened throughout the region. Renovation of the Uzbek Gene Bank, with support from ICARDA and IPGRI, has sensitized policymakers to improve other germplasm storage facilities. Considerable progress has been made in Kyrgyzstan, Tajikistan and Georgia on establishing national genetic resource centers with medium-term storage facilities. The genebank at the Genetic Research Institute of Azerbaijan has been made functional, and a new genebank established in Turkmenistan.

A new project to improve genebank facilities in the CAC region, funded by the Global Crop Diversity Trust, started in July 2005. It is being managed by ICARDA and the Program Facilitation Unit (PFU). The project will provide support for the most urgent needs of genebanks in the CAC countries, focusing on crops of critical importance.

A collection mission in Armenia in July 2005, in collaboration with the national program, Vavilov Institute of Russia, and CLIMA of Australia, yielded a number of valuable legume landraces. Within the framework of the CATCN Network, a working group on

H. E. Begench Atamuradov (center), Minister of Agriculture, Turkmenistan, with participants of the Eighth ICARDA-CAC Regional Coordination Meeting.

plant genetic resources (focusing on ICARDA's mandate crops) has been established in each CAC country. ICARDA provided all the eight groups with equipment (computers, digital cameras, projectors etc.) as well as training on PGR documentation.

Workshops and meetings

The eighth CAC Regional Coordination Meeting, held in Turkmenistan in March, was attended by 54 participants, including all NARS heads. Two other meetings for ADB-funded projects were organized in conjunction with this meeting: a Steering Committee meeting of the soil fertility project in Central Asia, and the inception workshop for an IWMI-ICARDA-ICBA project on degradation in the Aral Sea basin.

The Swedish International Development Cooperation Agency (SIDA) will begin activities in the CAC region in 2006. SIDA and ICARDA jointly organized a meeting on plant genetic resources in Aleppo in May 2005, attended by 27 participants from the eight countries, as well as IPGRI, PFU-CGIAR and the Global Crop Diversity Trust.

Human resource development

Capacity building efforts in 2005 included training programs for scientists, extension staff, farmers, and representatives from government departments. There were a total 67 participants from eight countries. The training covered various areas: PGR data management, disease survey techniques, IPM, seed production and related issues (seed policy, regulations, privatization, variety evaluation and release, variety maintenance, quarantine procedures, regional harmonization), and extension methods. Some of these programs will have multiplier effects. For example, participants in the course on PGR data management are expected to disseminate the database package and related skills to institutes holding *ex-situ* collections in their countries.

A disease survey training workshop in Azerbaijan.

At NARS request, special efforts were made to improve English language skills. Two intensive 3-month courses were held in Tashkent, Uzbekistan. Seven such courses have been conducted, and about 400 scientists have been trained to date.

Latin America Regional Program

The administrative office of the Latin America Regional Program (LARP) is located at CIMMYT in Mexico. The objective of LARP is to collaborate with NARS, NGOs, and private organizations in the region on research, human resource capacity building and networking. Several collaborative projects were implemented in 2005.

Collaborative projects

National level collaborative projects included the development of barley adapted to central Brazil, which has been in operation since 2001, aiming to provide support for the introduction of barley to a new agricultural frontier. The Cerrado Region is one of the few areas in the world where agriculture is expanding, and the local programs and companies believe that barley has a niche in the region. A comprehensive breeding program has been developed

ICARDA barley breeder, Dr Flavio Capettini (left), met with the National Barley Coordinator, Dr Euclydes Minella; the Regional Barley Breeder, Renato Amabile; and local farmers, during his visit to the new barley area in central Brazil.

for the region and new varieties adapted to the agro-ecological conditions are expected to be released soon.

The projects on the development of feed and forage barley adapted to Mexico continued. New projects on faba bean and chickpea were implemented in 2005. The introduction and development of germplasm, as well as exchange of information, will continue under these projects.

A project to promote barley in the north-west region of Mexico was initiated with the local farmers' association, using a participatory approach. Researchers from ICARDA assisted in launching the program. Meetings were held with local producers to discuss opportunities for new crops and identify training needs. Barley evaluation experiments were established and field days will be organized in 2006.

Technical assistance

Within the framework of the collaborative project with EMBRAPA in Brazil, ICARDA provided technical assistance to the barley breeding program for the selection and testing of new barley germplasm adapted to the region.

The ICARDA breeder visited Brazil to help evaluate experiments throughout the country. He discussed with local researchers the results obtained so far and opportunities for the release of new varieties. He also visited Ecuador in 2005 to strengthen the long-established and productive collaboration between ICARDA and the NARS.

Support Services

Geographic Information Systems Unit

The Geographic Information Systems Unit (GISU) was established in 2005, replacing the former MTP Project "Agroecological characterization for agricultural research, crop management and development planning". The specific mandate of GISU is to address ICARDA's growing needs for spatial database development and analysis through GIS, and to deliver mapping products, resource databases, methodologies for spatial analysis and agroecological characterization, training, and web portals for knowledge dissemination.

GISU supports ICARDA's research agenda with new and innovative GIS applications. A study in Syria provided the know-how for outscaling research on identifying the biophysical potential of water harvesting sites. A GIS-based decision-support system was developed – the "ICARDA Agroclimatic Tool", which helps quantify climatic stresses in different agro-ecological regions of CWANA. Building on the concept of resource poverty, a new approach to poverty mapping was developed that combines macro-level socioeconomic with micro-level environmental determinants of rural poverty.

GIS-embedded weather generators for characterizing climatic stresses

Agroclimatic characterization of the CWANA region is of paramount importance to map the occurrence of abiotic stresses, particularly extremes of temperature, heat and drought. ICARDA has a good climatic database which allows an adequate representation of the average climate.

However, a risk assessment of climatic stresses is basically an estimation of probabilities, which requires consideration of climatic variability. The low density of meteorological stations in the CWANA region, the high cost of meteorological data and many gaps in data records have made it hard to quantify these stresses in most parts of the region.

To address this problem a joint study was undertaken with the Plant Stress and Water Conservation Laboratory of the USDA's Agricultural Research Service. The objective was to develop a decision-support system, the "ICARDA Agroclimatic Tool". This application allows a user to select any agricultural location inside the ICARDA mandate region through a simple Windows user interface and obtain a set of relevant views on the climatic stresses at that location for the selected crop, growing season and soil type. The outputs are estimates of means and probabilities of exceeding user-defined thresholds for temperature and precipitation on a daily basis, or for user-defined time periods. The results can be viewed as graphs or exported as data files for use in other software applications.

The core of this application is a 'weather generator', which is actually a software module that generates artificial series of climatic data through a process of stochastic simulation. The weather generator was first parameterized for different parts of CWANA by using real climatic data series. The application was then developed using several public domain databases. Precipitation, minimum and maximum temperature data for 649 stations were obtained for the period 1977-1991 from two climatic data archives in the public domain, the Global Daily Summary Data (GLDS) and the Global Daily Climatology Network (GDCN). Additional databases were added: a crop database containing information for irrigation, the GTOPO30 Digital Elevation Model, and simplified maps of country boundaries, population centers, agricultural areas and station locations. All these databases are 'embedded' within the application.

The weather generator used is GEM6, developed by the USDA-ARS (www.eightnine.org/USClimateGEM.htm). The feasibility of using synthetic climatic data produced by the weather generator software, instead of real climatic data, depends on its ability to reproduce realistic estimates of the real climatic parameters. A validation was undertaken by comparing generated versus real data, and shows satisfactory agreement. The ICARDA Agroclimatic Tool currently has some limitations, notably the short time series used to parameterize the weather generator, but a newer version will use a longer and more up-to-date time series. The main benefit of the Tool is that the use of synthetic climatic data allows us to largely overcome the lack of climatic data available for ICARDA's mandate region. Its potential applications are manifold. First, the Tool will allow ICARDA's crop breeders to better target new varieties, with specific tolerances or sensitivities to various climatic stresses, to environments where these varieties have not been tested. We also expect the Tool will be used by the Genetic Resources Unit for more in-depth characterization in terms of stress tolerance of germplasm collected at specific sites. The Tool is also vital for the characterization of climatic variability and climatic stresses. For example, it will allow water management specialists to assess potential impact of rainfall and temperature variability on crop water and irrigation requirements. It also has applicability in climate change research.

Computer and Biometrics Support Unit

The most important achievement of the Computer and Biometrics Support Unit (CBSU) during 2005 was implementation of the web-based version of Oracle Applications (11i) covering financial, administrative and human resources areas, to meet new reporting requirements and overcome deficiencies in the previous system. Many functional processes were re-engineered, new reports developed, users trained, and access improved.

ICARDA's Local Area Network achieved very high availability of network and services (Exchange, Proxy/ISA, File Servers, Intranet) throughout 2005, approaching an uptime of 99.9%. ISA 2004 server was installed to replace an old VPN system for Active Directory and SMTP messaging. The wireless network was extended into the conference room, for both Satellite and LAN services. A new anti-virus software, Trend Office Scan was installed on servers and client PCs. Secure access for the Oracle outreach project was set up and tested successfully. SSL-Explorer was installed to give remote access to the Intranet. GoRemote software was installed for traveling users to replace expensive TAS access. We successfully set up a second standby MS Exchange server and a secure certificate web server for traveling users.

The Internet bandwidth was further upgraded to 2 Mbit/sec. The ICARDA Intranet was developed further with new pages and services.

Support to ICARDA outreach offices continued. The ICARDA School was supported for hardware maintenance, local area network, internet access, and Oracle Applications on-line reporting. Site surveys on internet service were carried out for the Tashkent,

Kabul and Cairo offices.
As part of ICARDA's involvement in the CGIAR ICT-KM projects, CBSU participated in the CGXchange project, and initiated the first phase of the "Utilization of intelligent information systems for crop protection" project. Considerable work was done on capturing the knowledge base for barley and chickpea in cooperation with scientists. The Center hosted the annual meeting of the CGIAR information technology managers in June.


Participants of the annual meeting of the CGIAR Information Technology Managers, held at ICARDA headquarters.

The Unit completed the design and development of a web-based soil database and initiated data loading. Further development was carried out to enhance and maintain the meteorological database, and it was migrated to an Oracle 9i database. A new version of the Meta database was introduced. A system requirements study document was developed for a database on Participatory Plant Breeding.

Data loading for the Project Manager system was largely completed. The new Payroll System covering all contract staff at headquarters and outreach offices was developed and implemented successfully. For the new payroll system, 12 programs, 31 reports and 29 forms were developed or modified.

The Unit provided 110 biometric consultancies to ICARDA researchers. Support on statistical software and data management was provided on over 60 occasions. Online bio-computing facilities were provided to users on 73 occasions.

Statistical designs were developed for various experiments including those for evaluating the effect of irrigation on wheat; chickpea seed treatments and foliar treatments; safflower variety, row-spacing, and seed rate; seed storage factors; response of barley genotypes to vernalization and photoperiod; application of phosphorus and organic matter and water on soil nutrients extracted in the resin polymer.

Statistical analyses were carried out for numerous datasets – identifying winter and facultative wheat genotypes and classifying them into categories for drought tolerance and input responsiveness; diversity and selection coefficients using data on pathogen distribution on a number of barley hosts; evaluating wheat genotypes under protection treatments in a crop-loss experiment on yellow rust; performance of mixtures of genotypes; evaluating effectiveness of core sampling methods on the coverage of population parameters using core sample based confidence intervals; fitting genetic ratios on *Ascochyta* blight score in faba bean and estimation of effective number of factors controlling the disease; evaluating data from meat tasting experiments; behavior preferences of sheep on grazing of shrubs; screening of models for validating evapotranspiration using experimental data; and data on phosphorus dynamics.

Training

CBSU participated in the Generation Challenge Program on Bioinformatics capacity building and in conferences to provide training on statistical analysis of gene expression data and on Monte Carlo methods. Five biometrics courses for 83 participants were offered.

Communication, Documentation and Information Services

Publications and media relations

The Center produced a wide range of publications in 2005, targeted at various audiences. These included a weekly newsletter; *Caravan*, a periodical describing ICARDA's research to non-technical readers; corporate and program annual reports; newsletters for regional seed network and the dryland agrobiodiversity project, and a number of scientific reports and workshop proceedings. Six titles were produced in the "Ties that Bind" series which describes collaboration between ICARDA and individual countries or donor agencies. The publications were distributed widely to NARS and other partners worldwide. A large number of posters were produced for scientific conferences and book fairs.

The New Scientist carried a feature article "Returning Farmland to Productivity," inspired by 'Healing Wounds,' produced at ICARDA for the CGIAR. The article brought increased visibility to ICARDA and other CGIAR centers, and was subsequently cited in several media stories. The Canadian Broadcasting Corporation radio network did a feature on rebuilding agriculture, and the Crawford Fund published a brochure (drawing material from Healing Wounds) on Australia's support to rebuilding agriculture in various countries.

'Healing Wounds' was formally launched in Kabul in February 2005, by the Afghanistan Minister of Agriculture. The launch was covered by a large number of mdia representatives including those from BBC, Voice of America, the Afghanistan print media, and local and regional radio and TV stations.

The regional and international media continued to provide positive coverage of ICARDA's work. The clippings are posted on ICARDA's website (www.icarda.org/Media.htm). Key stories appeared in a number of regional newspapers and magazines and also in Australia, Japan and elsewhere.

A BBC journalist visited ICARDA in May to film the Center's work on Sunn pest management. The documentary featured in BBC's 'Hands On' program, viewed by more than 270 million households worldwide. A Swedish TV journalist visited ICARDA to familiarize himself with the research programs, and featured the Center's work in a documentary on Syria, for Swedish TV.

Website and multimedia products

The Center's website continued to attract increased number of visitors, with over 1 million during 2005. On average, the English version of the website received over 6000 hits, and the Arabic version about 1000 hits per day.

Five ICARDA training modules for online learning were redesigned, and uploaded to the CGIAR learning objects repository and learning management system.

A number of multimedia products were developed in 2005. These included video films in English and Arabic – including a short film in memory of the late Dr Robert Havener, which was shown at the CGIAR AGM 2005. Video footage was recorded on ICARDA's work on Sunn pest control in Syria and Turkey, as well as on small-scale milk processing initiatives in Syria. Video footage on various research projects was shared with BBC and Al-Jazeera TV.

Library and documentation services

The library added to its collection over 275 books, 800 issues of journals and annual reports, and updates of AGRIS databases on CD-ROMs. It fulfilled over 1900 requests for literature searches and other services from NARS scientists. The Virtual Library (CD-ROM library) on the Center's Intranet was enriched with additional links to useful reference sources, and was extensively used by ICARDA scientists, trainees and visitors.

In 2005, the Center's Library installed NewGenLib, an Integrated Library Management System, which will allow ICARDA to computerize all library activities, and network all ICARDA program libraries at headquarters and in regional offices. Considerable progress was made on ICARDA's digitization project, which aims to consolidate information from a vast number of reports, technical papers and other publications into a comprehensive searchable database.

The Unit staff participated in several meetings and consultations with professional associations, regional forums, FAO and other agencies to strengthen library and documentation services in the CWANA region. These included, for example, the GLOBAL-RAIS project of GFAR, which will assist regional forums to develop and implement their own regional agricultural information systems. The Center provided a resource person for the CG online learning initiative, and also expanded collaboration with FAO to strengthen support to NARS.

ICARDA continued to maintain and strengthen its twinning agreement with agricultural libraries in Sudan and Egypt.

Training

The Unit continued to help strengthen NARS capacity to document, manage and disseminate information. Training courses were offered on science writing and PowerPoint presentations. In collaboration with FAO, a two-week training course on "Management of electronic documents and web databases," was offered, which brought together participants from 10 countries.

Human Resource Development Unit

During the year 2005, ICARDA offered training opportunities to 1196 national scientists from 49 countries within and outside the CWANA region. In addition, 58 national scientists from developing and developed countries are conducting their graduate research training for MSc and PhD degrees, under the joint supervision of ICARDA and the respective parent university or institution. About 20% of training participants in 2005 were women.

ICARDA continued its strategy of gradually decentralizing training activities by offering more training courses at locations outside its headquarters in Aleppo. The Center offered 22 courses at headquarters and 35 in-country, regional and sub-regional courses. Nearly two-thirds of participants were trained in courses organized outside headquarters, in close collaboration with NARS.

In response to increasing (and evolving) demand for training from NARS, the Human Resources Development Unit (HRDU) facilitated and coordinated a number of training courses for external-funded projects, for example the Agricultural Higher Education and Development (AHEAD) Project in Iraq, funded by USAID and the University of Hawaii; the Netherlands-funded project on IPM in Egypt; as well as projects funded by the CGIAR Gender and Diversity Committee, FAO, ICBA, and JICA.

The different types of courses are summarized below:

- Twenty-two training courses and workshops conducted at ICARDA headquarters in

Aleppo, involving scientists from NARS, universities and other organizations, NGO staff, farmers, and scientists and administrators from CGIAR Centers.

- Regional training courses held in Afghanistan, Bangladesh, Egypt, Eritrea, Iran, Morocco, Oman, Sudan, Syria, UAE, Uzbekistan, Turkey, and Yemen, in collaboration with national research and extension agencies, other national and regional institutions, CGIAR Centers, JICA, and international organizations including USAID, DFID, FAO, IFAD and the European Commission.
- In-country courses for national researchers, extension and NGO staff and farmers, conducted in 11 countries. Some courses were conducted in one country for the benefit of participants from another: for example, training in greenhouse management conducted in Egypt for participants from Afghanistan.

A training course in biotechnology in progress at ICARDA.

Collaboration in human resources development was further extended not only with NARS, but also with regional and international research and training institutes such as JICA, World Bank, FAO, IFAD, AFESD, ADB, GEF, ICBA, USAID, SYNGENTA, CLAES, universities, and several CGIAR Centers. Inter-Center collaboration was also strengthened through participation in the IARCs Inter-Center Training Group and the exchange of training databases with other CGIAR programs. ICARDA was actively involved in CGIAR activities related to human resource development, including the Global Open Food and Agricultural University (GO-FAU), Virtual University, and initiatives on distance education, e-learning and knowledge management and dissemination. ICARDA's training database was also updated and placed on the Center's intra and internet websites.

ICARDA is also working with the Japanese International Cooperation Agency (JICA), the Syrian Planning Commission, and national authorities in Afghanistan and Iraq for implementation of training courses, workshops and seminars under the newly approved 5-year Third Country Training Programs for Afghanistan and Iraq. Another project proposal for graduate and undergraduate studies for Afghan students was recently prepared in collaboration with Mega-Project 6 and submitted to USAID for funding. The CCER on human resources development and capacity building at ICARDA was launched in November 2004 and will be completed in early 2006.

Appendix 1 - Journal Articles

The following list covers journal articles published in 2005 by ICARDA researchers, many of them in collaboration with colleagues from national programs. A complete list of publications, including book chapters and papers published in conference proceedings, is available on ICARDA's web site: www.icarda.org.

Abd-El-Moneim, A.M., M. Baum, and A. Larbi. 2005. Grasspea research at ICARDA: current status and future strategy. Journal of Food, Agriculture and Environment 3 (2): 345.

Abdel Ghani, A.M., H.K. Parzies, S. Ceccarelli, S. Grando, and H.H. Geiger. 2005. Estimation of quantitative genetic parameters for outcrossing-related traits in barley. Crop Science 45 (1): 98-105.

Abidou, H., S. Valette, J.P. Gauthier, R. Rivoal, A. El-Ahmed, and A. Yahyaoui. 2005. Molecular polymorphism and morphometrics of species of the *Heterodera avenae* group in Syria and Turkey. Journal of Nematology 37 (2): 146-154.

Abidou, H., A. El-Ahmed, J. Nicol, N. Bolat, R. Rivoal, and A. Yahyaoui. 2005. Occurrence and distribution of species of the *Heterodera avenae* group in Syria and Turkey. Nematologia Mediterranea 33: 195-201.

Al Yassin, A., S. Grando, O. Kafawin, A. Tell, and S. Ceccarelli. 2005. Heritability estimates in contrasting environments as influenced by the adaptation level of barley germplasm. Annals of Applied Biology 147: 235-244.

Alary, V. and M. El-Mourid. 2005. Food policies of Maghreb and their effects on the agropastoral societies. Les politiques alimentaires au Maghreb et leurs conséquences sur les sociétés agropastorales. Revue Tiers Monde 36 (184): 785-810 (in French).

Aquino de Muro, M., S. Elliott, D. Moore, B.L. Parker, M. Skinner, W. Reid, and M. El Bouhssini. 2005. Molecular characterization of *Beauveria bassiana* isolates obtained from overwintering sites of sunn pests (*Eurygaster* and *Aelia* species). Mycological Research 109 (3): 294-306.

Barrios, E., J.G. Cobo, I.M. Rao, R.J. Thomas, E. Amezquita, J.J. Jimenez, and M.A. Rondon. 2005. Fallow management for soil fertility recovery in tropical Andean agroecosystems in Colombia. Agriculture, Ecosystems and Environment 110 (1-2): 29-42.

Bekele, E., S. Kumari, K. Ali, A. Yusuf, K.M. Makkouk, M. Aslake, M. Ayalew, G. Girma, and D. Hailu. 2005. Survey of viruses affecting legume crops in the Amhara and Oromia regions of Ethiopia. Phytopathologia Mediterranea 44 (3): 235-246.

Chabane, K., G.A. Ablett, G.M. Cordeiro, J. Valkoun, and R.J. Henry. 2005. EST versus genomic derived microsatellite for genotyping wild and cultivated barley. Genetic Resources and Crop Evolution 52 (7): 907-913.

Choo, T.M., B. Vigier, K.M. Ho, S. Ceccarelli, S. Grando, and J.D. Franckowiak. 2005. Comparison of black, purple, and yellow barleys. Genetic Resources and Crop Evolution 52: 121-126.

Eberbach, P.L. and M. Pala. 2005. Crop row-spacing and its influence on the partitioning of evapotranspiration by winter-grown wheat in northern Syria. Plant and Soil 268 (1): 195-208.

Einfeldt, C.H.P., S. Ceccarelli, S. Grando, A. Gland-Zwerger, and H.H. Geiger. 2005. Heterosis and mixing effects in barley under drought stress. Plant Breeding 124(4): 350-355.

El-Haramein, F.J. and H. Nakkoul. 2005. Predicting nutritional and antinutritional components in grasspea by near infrared reflectance (NIRS). Journal of Food, Agriculture and Environment 3 (2): 347.

Gahoonia, T.S., O. Ali, A. Sarker, M.M. Rahman, and W. Erskine. 2005. Root traits, nutrient uptake, multi-location grain yield and benefit-cost ratio of two lentil (*Lens culinaris Medikus*) varieties. Plant and Soil 272 (1/2) 153-161.

Grando, S., M. Baum, S. Ceccarelli, A. Goodchild, F. Jaby El-Haramein, A. Jahoor, and G. Backes. 2005. QTLs for straw quality characteristics identified in recombinant inbred lines of a *Hordeum vulgare* × *H. spontaneum* cross in a Mediterranean environment. Theoretical and Applied Genetics 110 (4): 688-695.

Gul, A., F. Rida, A. Aw-Hassan, and O. Buyukalaca. 2005. Economic analysis of energy use in groundwater irrigation of dry areas: A case study in Syria. Applied Energy 82: 285-299.

Haddad, N., M. Singh, and Q. Mamdouh. 2005. On-farm evaluation of improved barley production technology packages in Jordan. Jordan Journal of Agricultural Sciences 1 (1): 1-11.

Hamwieh, A., S.M. Udupa, W. Choumane, A. Sarker,

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Appendix 2 - Graduate Theses Produced with ICARDA's Joint Supervision

Master of Science

Syria, Aleppo University

El-Ashkar, Haitham. 2005. The effect of Mashreq/Magreb project on the development of dry areas (Om Al-Ammad - Hamma, Al-Mahmoudly - Al-Raqqa) in Syria. 168 pp. (In Arabic, English summary).

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Syria, Tishreen University

Al-Naeb, Husam. 2005. Sustainable management of legumes and fertilization in olive groves, northwest Syria, economic aspects and their impact on decreasing soil erosion and physical and chemical properties of the studied soil. 127 pp. (In Arabic, English summary).

Appendix 3 - Agreements signed in 2005

ICBA/PFU

2 February 2005. Memorandum of Understanding between the International Center for Biosaline Agriculture (ICBA), UAE, and the Program Facilitation Unit (PFU) of the CGIAR Program for Central Asia and the Caucasus hosted by ICARDA at its Regional Office in Tashkent, Uzbekistan

Sudan

16 March 2005. Agreement between the Government of Sudan, Ministry of Science and Technology and ICARDA.

Egypt

1 May 2005. Memorandum of Understanding between Ain Shams University and ICARDA.

Hashemite Kingdom of Jordan

1 May 2005. Memorandum of Understanding between the Jordan University of Science and Technology (JUST), and ICARDA.

Kingdom of Saudi Arabia

May 2005. Memorandum of Understanding between the Ministry of Agriculture and ICARDA.

28 June 2005. Memorandum of Understanding between the University of Jordan and ICARDA.

Jordan, Lebanon, the Palestinian National Authority and Syria

29 June 2005. Regional Alliance for Promoting Conservation of Agrobiodiversity and Exchange of Genetic Resources between the Ministries of Agriculture of Jordan, Lebanon, the Palestinian National Authority and Syria (ICARDA is a witness).

United Nations

29 June 2005. Memorandum of Understanding between the United Nations Development Program/Program of Assistance of the Palestinian People (UNDP/PAPP).

Arab Authority for Agricultural Investment and Development

26 September 2005. Memorandum of Understanding between the Arab Authority for Agricultural Investment and Development (AAAID) and ICARDA.

Association of Agricultural Research Institutions in the Near East and North Africa

23 October 2005. Memorandum of Understanding between ICARDA and the Association of Agricultural Research Institutions in the Near East and North Africa (AARINENA) and ICARDA.

Syria

15 November 2005. Memorandum of Understanding between Aleppo University and ICARDA.

Iraq

17 November 2005. Memorandum of Understanding between the University of Dhouk and ICARDA.

Mexico

5 December 2005. Memorandum of Understanding between the International Maize and Wheat Improvement Center (CIMMYT) and ICARDA.

Appendix 4 - Restricted-Fund Projects

ICARDA's research program is implemented through six Mega-Projects, as detailed in the Center's Medium-term Plan. Restricted-fund project activities are supported by restricted funding that is provided separately from the Center's unrestricted core funding. Restricted funding includes donor-attributed funding (core funds allocated by the donor to specific activities) and project-specific grants. The financial contributions by the respective donors are reported in Appendix 7. Reports on the activities listed are included in the appropriate sections of this Annual Report.

The Restricted-fund Projects operational during 2005 are listed below.

AFESD (Arab Fund for Economic and Social Development)

- Technical assistance to ICARDA's activities in Arab countries (training Arab nationals and support to Arab national programs)
- Sustainable management of natural resources and improvement of major production systems of the Arabian Peninsula
- Options for coping with increased water scarcity in agriculture in West Asia and North Africa
- Developing sustainable livelihoods of agropastoral communities of West Asia and North Africa

ASIAN DEVELOPMENT BANK

- On-farm soil and water management for sustainable agricultural systems in Central Asia
- Enabling communities in the Aral Sea basin to combat land and water resource degradation through the creation of 'bright' spots

AUSTRALIA

ACIAR (Australian Centre for International Agricultural Research)

- Lentil and Lathyrus in the cropping systems of Nepal: improving crop establishment and yield of relay and post-rice-sown pulses in the *terai* and mid-hills
- Genetic resource conservation, documentation and utilization in Central Asia and the Caucasus
- Plant health management for faba bean, chickpea and lentils
- Ensuring productivity and food security through sustainable control of yellow rust of wheat in Asia
- Better crop germplasm and management for improved production of wheat, barley and pulse and forage legumes in Iraq

Cooperative Research Centre for Molecular Plant Breeding

- Post-doctoral Fellow in barley improvement

GRDC (Grains Research and Development Corporation)

- Technologies for the targeted exploitation of the N.I. Vavilov Institute of Plant Industry (VIR), ICARDA and Australian bread wheat landrace germplasm
- CIPAL (Coordinated Improvement Program for Australian Lentils)
- Coordinated improvement of chickpeas in Australia – Northern Region module
- Faba bean improvement - Northern Region
- Associate Expert in legume pathology
- Collaborative barley breeding for low-rainfall environments
- Durum industry development - Collaboration with ICARDA to accelerate cultivar improvement for adaptation across all production regions

Grain Foods Cooperative Research Centre Ltd

- Genetic manipulation of pulses for improved flavor and color
- Novel germplasm for food and malt (barley products)

AUSTRIA

- Production diversification and income generating options for small-scale resource poor livestock farmers of the dry areas: The case of lamb fattening in WANA

BRAZIL

EMBRAPA (Empresa Brasileira de Pesquisa Agropecu□ria / Brazilian Agricultural Research Corporation

- Cooperative activities between ICARDA and EMBRAPA

CANADA

CGIAR-Canada Linkage Funds
- Characterization and Molecular Mapping of Drought Tolerance in Chickpea

Canada Fund for Africa
- Support to research and capacity building activities in Eritrea, Ethiopia, Mauritania and Sudan

Crop Development Centre, University of Saskatchewan
- Off-season evaluation of *Ascochyta* blight reaction in chickpea

CGIAR CHALLENGE PROGRAMS

Generation Challenge Program
- Commissioned research
- Allele mining based on non-coding regulatory SNPs in barley germplasm

Harvest Plus
- Identification of barley germplasm accessions with high concentration of □-carotene, iron and zinc
- Identification of lentil germplasm accessions with high concentration of □-carotene, iron and zinc

Challenge Program on Water and Food
- Improving water productivity of cereals and food legumes in the Atbara river basin of Eritrea.
- Strengthening livelihood resilience in upper catchments of dry areas by integrated natural resources management.
- Improving on-farm agricultural water productivity in the Karkheh river basin, Iran

CGIAR ICT-KM Program

- Utilization of Intelligent Systems for Plant Protection

CGIAR SYSTEMWIDE PROGRAMS

CGIAR Collaborative Program for Central Asia and the Caucasus
- Program Facilitation Unit

Systemwide Livestock Program (SLP)
- Low-toxin grasspea for improved human and livestock nutrition and ecosystems health in drought-prone areas in Asia and Africa

IWMI Comprehensive Assessment Program
- Assessment of water harvesting and supplemental irrigation potential in arid and semi-arid areas of West Asia and North Africa

DENMARK

- Integrated disease management to enhance barley and wheat production in Eritrea.

EC (European Commission)

EC Attributed Funding
- Integrated Gene Management: Conservation, enhancement and sustainable use of agrobiodiversity in dry areas

EC 6th Framework International Cooperation (INCO)
- Mapping adaptation of barley to drought environments (MABDE)
- Improving durum wheat for water use efficiency and yield stability through physiological and molecular approaches (IDuWUE)
- Consultative Workshop on Participatory Plant Breeding (CONPAB)
- Exploiting the wheat genome to optimize water use in Mediterranean ecosystems (TRITIMED)

ERF (Economic Research Forum) FEMISE Program
- Les obstacles aux transferts technologiques dans les petites et moyennes exploitations agricoles des zones arides et semi arides du Maghreb. Discussion sur les conditions d'amélioration de la productivité en Algérie, Maroc et Tunisie

FAO (Food and Agriculture Organization of the United Nations)

- Applied research to improve and maintain seed quality for fodder shrubs and grass species used for rangeland rehabilitation
- Preparation of the proceedings of the International Sunn Pest Conference and follow-up activities for the development of IPM strategies for Sunn Pest
- Applied research component of project GCP/PAK/095/USA "Food Security/Poverty Alleviation in Arid Agriculture Balochistan - Pilot Project Phase"
- Technical Cooperation Program (TCP) "Training on Orobanche weed management in leguminous crops"
- TCP "Sustainable agriculture practices in the drought affected region of Karakalpakstan"
- TCP "Improvement of cereals, leguminous, oil and forage crops seed production":

Coordination and implementation of activities related to the establishment of an efficient and integrated seed production system
- Expert Group Meeting on Harnessing Biotechnology and Genetic Engineering for Agricultural Development in the Near East and North Africa
- Organization of the North Africa and Nile Valley Workshop on Technical Support to the International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) - Creating an "Intersectoral" Dialogue on PGRFA Conservation, Breeding and Seeds
- Organization of the West Asia and Arabian Peninsula Workshop on Technical Support to the International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) - Creating an Intersectoral Dialogue on PGRFA Conservation, Breeding and Seeds

FRANCE

CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement)
- Joint appointment of a CIRAD Research Fellow on institutional options for rangeland management

Service of Cooperation and Cultural Action of the French Embassy in the Republic of Yemen
- Supporting rural development and food security in the terraces of Yemen: Adoption of sustainable protected agriculture technology for the production of cash crops in the Taez Region

GERMANY

- An integrated approach to sustainable land management in dry areas
- Functional genomics of drought and cold tolerance in chickpea and lentil
- Exploration of genetic resources collections at ICARDA for adaptation to climate change

GLOBAL CROP DIVERSITY TRUST

- Inventory of *ex-situ* collections of Annex 1 crops in Central Asia and the Caucasus
- Establishment of a Regional Plant Genetic Resources Information Network for the Central Asia and Caucasus (CAC) Region
- Improving the facilities of genebanks in the CAC Region

GEF (Global Environment Facility) / UNDP (United Nations Development Programme)

- Conservation and sustainable use of dryland agrobiodiversity in Jordan, Lebanon, Syria and the Palestinian Authority

GULF COOPERATION COUNCIL (GCC)

- Development of sustainable date palm production systems in the GCC countries of the Arabian Peninsula

IDRC (International Development Research Centre)

- Strengthening seed systems for food security in Afghanistan
- Institutionalizing participatory plant breeding within national plant breeding systems: costs and benefits
- International Conference on "Promoting community-driven conservation and sustainable use of dryland agrobiodiversity"
- Workshop on "Participatory plant breeding varieties: ownership, access and benefits
- Recognition, access, and benefit sharing in participatory plant breeding programs in Syria, Jordan, Egypt, Eritrea

IFAD (International Fund for Agricultural Development)

- Sustainable management of natural resources and improvement of major production systems of the Arabian Peninsula
- Program for strengthening research and development to improve marketing of small ruminant products and income generation in dry areas of Latin America
- Program to foster wider adoption of low-cost durum technologies
- Program for enhancing food security in the Nile Valley and Red Sea region: Technology generation and dissemination for sustainable production of cereals and cool-season food legumes
- Technical assistance for accelerated project performance in North Africa

- Small ruminant health - improved livelihood and market opportunities for poor farmers in the Near East and North Africa region
- Community-based optimization of the management of scarce water resources in agriculture in West Asia and North Africa
- Developing sustainable livelihoods of agropastoral communities of West Asia and North Africa
- Social capital assessment in the area of Southern Region Development Project, Tunisia
- Linking the Virtual Information and Communication Centre (VICC) serving Mexico Investment and Grant Projects with FIDAMERICA

IRAN

Scientific and technical cooperation and training.

ITALY

Italy Attributed Funding
- Durum wheat germplasm improvement for increased productivity, yield stability and grain quality
- Barley germplasm improvement for increased productivity
- Food legume germplasm improvement for increased systems productivity: Chickpea improvement

JAPAN

Japan Attributed Funding
- Improvement, intensification and diversification of sustainable crop and livestock production systems in dry areas
- Improving income of small-scale producers in marginal agricultural environments: small ruminant milk production and milk derivatives, market opportunities and improving value added returns

JICA (Japan International Cooperation Agency)
- Third Country Training Program in Crop Improvement and Seed Technology
- Japanese Technical Cooperation Project for Enhancing Human Resources Development in Iraq
- JICA volunteer in research on small ruminant genetic diversity

JIRCAS (Japan International Research Center for Agricultural Sciences)
- Evaluation of drought-tolerant wheat germplasm
- Post-doctoral Fellow in drought physiology

KOREA: Rural Development Administration (RDA), Republic of Korea

Collaboration in barley research

MAURITANIA

- Technical assistance to Project Gestion des Parcours et Developpement de l'Elevage (PADEL)

MOROCCO

Morocco Collaborative Grants Program (MCGP)
- Barley improvement in the arid and semi-arid areas of Morocco
- Introgression of selected genetic disease resistance into durum wheat for the rainfed areas of Morocco
- Reinforcement of plant genetic resources conservation and utilization at Settat gene bank
- Development of an integrated natural resources management framework for sustainable agriculture in Central Morocco
- Integrated pest management in the cereals /food legumes cropping systems in Morocco

OPEC FUND FOR INTERNATIONAL DEVELOPMENT

- Institutionalization and Scaling-up of Participatory Barley Breeding in WANA
- Sustainable management of natural resources and improvement of major production systems of the Arabian Peninsula
- Community-based research for agricultural development and sustainable resource management in Afghanistan

PAKISTAN

- Cooperation in the applied research component of the Barani Village Development Project (BVDP)

SWITZERLAND

Swiss Agency for Development and Cooperation (SDC)
- Associate Expert in poverty analysis
- Sustainable management of the agropastoral resource base in the Maghreb
- Communal management and optimization of mechanized micro-catchment water harvesting for combating desertification in the East Mediterranean region
- Improving the livelihoods of rural communities and natural resource management in the

mountains of the Maghreb countries of Algeria, Morocco and Tunisia

Swiss Centre for International Agriculture (ZIL), Federal Institute of Technology Zurich (ETHZ)
- Research Fellowship project on improving resistance to barley scald

TURKEY

- Technical assistance to Southeast Anatolia Project Regional Development Administration

UNITED KINGDOM

DFID (Department for International Development) Competitive Research Facility
- Integrated pest management of Sunn Pest in West Asia
- Management of Research in Alternative Livelihoods Fund (RALF), Afghanistan
- Cultivation of mint as a viable alternative livelihood in East and North-East of Afghanistan
- Improved rural incomes in Afghanistan from better production and sales of milk products

UNCCD (United Nations Convention to Combat Desertification)

Global Mechanism of the UNCCD
- Regional Environmental Management Officer, Tashkent
- Development of a facilitation unit for the establishment of a Regional Program for Sustainable Development of the Drylands of West Asia and North Africa
- Regional Program for Sustainable Development of the Drylands of West Asia and North Africa: Inventory of activities and gap analysis

UNCCD Sub-Regional Action Program (SRAP) for West Asia
- Integrated natural resources management programme to combat desertification in Lebanon and Jordan (Pilot Projects)

UNESCO

- Sustainable Management of Marginal Drylands (SUMAMAD) - Khanasser Valley Integrated Research Site, Syria.
- Sustainable Management of Marginal Drylands (SUMAMAD) - Zeuss Koutine site, Tunisia
- Third International SUMAMAD Workshop
- Basic research on the elaboration, elucidation and implementation of the principles for the biological control of Sunn pest populations in Kazakhstan and the Kyrgyz Republic

UNITED STATES OF AMERICA

USAID (United States Agency for International Development) Linkage Funds
- Cooperation with University of California, Davis: Evaluation of pulse genetic resources
- Cooperation with University of Delaware: Using information technology for improving water use efficiency
- Cooperation with Washington State University: Rust and Stemphylium blight resistance in lentil
- Cooperation with University of Vermont: Sunn pest biocontrol
- Cooperation with Yale University: Assessing the impact of agricultural research on rural livelihoods and poverty alleviation

USAID Rebuilding Agricultural Markets Program (RAMP), Afghanistan
- Village-based seed enterprise development in Afghanistan
- Demonstrating new technologies in farmers' fields to facilitate rapid adoption and diffusion
- Introducing protected agriculture for cash crop production in marginal and water deficit areas of Afghanistan

USAID Cereal Comparative Genomics Initiative, Sub-contract with Prime Contractor University of Minnesota
- Mining wild barley in the Fertile Crescent: A genomics approach for exploiting allelic diversity for disease resistance in barley

USAID IPM CRSP (Integrated Pest Management Collaborative Research Support Program), Sub-contract with Prime Contractor Michigan State University
- Ecologically-based Participatory and Collaborative IPM Research and Capacity Building Program in Central Asia

USDA/ARS (United States Department of Agriculture/Agricultural Research Service)
- Collection of plant genetic resources in the Central Asian and Caucasus region
- Climatological analysis as a tool

for agricultural decision making in dry areas
- Identifying wheat and barley germplasm resistant to Syrian and United States populations of the Russian Wheat Aphid

USDA/FAS (United States Department of Agriculture/Foreign Agricultural Service)
- Biological diversity, cultural and economic value of medicinal, herbal and aromatic plants in southern Tunisia
- Biological diversity, cultural and economic value of medicinal, herbal and aromatic plants in Morocco
- Partnership to improve rural livelihoods in West Asia and North Africa through strengthened teaching and research on sheep and goat production.
- GIS for watershed management in the arid regions of Tunisia.
- Research on improving productivity of oats as a priority forage species in Tunisia
- Biological control of weeds with plant pathogens

WORLD BANK

- Regional initiative for dry land management
- International Assessment of Agricultural Science and Technology for Development (IAASTD), CWANA Sub-global Component

Appendix 5 - Collaboration with Advanced Research Institutes and Regional and International Organizations

CGIAR centers and regional/international organizations

ACSAD (The Arab Center for the Studies of Arid Zones and Dry Lands)

- Joint workshops, conferences and training
- Exchange of germplasm.
- Collaboration in integrated natural resource management for combating desertification in Syria, Jordan, Yemen and Lebanon
- Collaboration in conservation and sustainable use of dryland agro-biodiversity in Jordan, Lebanon, Palestinian Authority and Syria.
- Collaboration in regional program for sustainable development of the drylands in WANA

CIAT (Centro Internacional de Agricultura Tropical)

- ICARDA participates in the Systemwide Programme on Soil Water and Nutrient Management (SWNM) and in the Systemwide Programme on Participatory Research and Gender Analysis (PRGA), both coordinated by CIAT
- ICARDA is participating in HarvestPlus (Challenge Program on Biofortified Crops for Improved Human Nutrition), led by CIAT and IFPRI
- CIAT is the managing center for Theme 2 of the Challenge Program on Water and Food and collaborates in the project led by ICARDA on strengthening livelihood resilience in the Karkeh River Basin in Iran

CIHEAM (International Center for Advanced Mediterranean Agronomic Studies)

- Joint training courses and information exchange
- ICARDA is participating in a project on mapping adaptation of barley to drought environments coordinated by CIHEAM
- CIHEAM, ICARDA and FAO-RNE are co-conveners of the Network on Drought Management for the Near East, Mediterranean and Central Asia (NEMEDCA Drought Network)
- ICARDA is a member of FAO/CIHEAM SARD (Sustainable Agriculture and Rural Development) Mountain Mediterranean Network
- Collaboration in Consultative Workshop on Participatory Plant Breeding
- Study of the tolerance of ICARDA mandate crops to salinity and drought
- Joint supervision of graduate students on improved water management

CIMMYT (International Center for the Improvement of Maize and Wheat)

- An ICARDA barley breeder is seconded to CIMMYT.
- CIMMYT's outreach program in Turkey and ICARDA's Highland Regional Program share facilities in Ankara, Turkey and collaborate with Turkey in a joint Winter and Facultative Wheat Improvement Program
- CIMMYT participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA
- ICARDA is participating in the Generation Challenge Program (Unlocking Genetic Resources in Crops for the Resource Poor) led by CIMMYT and IRRI

CIP (International Potato Center)

- CIP participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA

ESCWA (UN Economic and Social Commission for West Asia)

- Joint publications and seminars on on-farm water use efficiency

FAO (Food and Agriculture Organization of the United Nations)

- ICARDA and FAO are co-sponsors of AARINENA
- ICARDA participates in FAO's AGLINET cooperative library network, AGRIS and CARIS.
- ICARDA cooperates with FAO in the production of the Arabic version of the agricultural multilingual thesaurus AGROVOC
- ICARDA participates in FAO's Global Animal Genetic Resources Program and the FAO/CIHEAM Cooperative Research Network on Sheep and Goats, Genetic Resources Sub-Network
- ICARDA cooperates with the FAO Commission on Plant

Genetic Resources
- Jointly organized regional workshops on "Technical Support to the International Treaty on Plant Genetic Resources for Food and Agriculture: Creating an Intersectoral Dialogue on Plant Genetic Resources Conservation"
- ICARDA is a member of FAO/CIHEAM SARD (Sustainable Agriculture and Rural Development) Mountain Mediterranean Network
- ICARDA participates in the Inter-Agency Task Forces convened by the FAO-RNE (FAO Regional Office for the Near East)
- FAO-RNE, ICARDA and CIHEAM are co-conveners of a Network on Drought Management for the Near East, Mediterranean and Central Asia (NEMEDCA)
- FAO-RNE and ICARDA coordinate the Oat-Vetch Regional Network (REMAV)
- FAO-RNE and ICARDA collaborate in applied research to improve and maintain seed quality for fodder shrubs and grass species used for rangeland rehabilitation
- Collaboration in a project on food security and poverty alleviation in Balochistan, Pakistan
- Collaboration in a Technical Cooperation Program on *Orobanche* control in food legumes

ICBA (International Center for Biosaline Agriculture)
- Collaboration in research on salinity management in Central Asia.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)
- ICRISAT participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA
- ICARDA and ICRISAT are co-conveners of the Consortium on Desertification, Drought, Poverty, and Agriculture (DDPA)
- ICARDA and ICRISAT are partners in a study of yield gaps within the Comprehensive Assessment of Water Management of the Systemwide Program on Water
- Collaboration in the development and utilization of intelligent systems in plant protection

IFPRI (International Food Policy Research Institute)
- ICARDA is participating in HarvestPlus (Challenge Program on Biofortified Crops for Improved Human Nutrition), led by IFPRI and CIAT
- ICARDA participates in the System Wide Program on Collective Action and Property Rights (CAPRi) coordinated by IFPRI
- IFPRI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA

IITA (International Institute of Tropical Agriculture)
- ICARDA is participating in the Systemwide Program on Integrated Pest Management, coordinated by IITA

ILRI (International Livestock Research Institute)
- ICARDA participates in the Systemwide Livestock Program coordinated by ILRI
- ILRI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA
- ILRI and ICARDA share a joint position on animal epidemiology
- ILRI and ICARDA cooperate in a joint project on small ruminant health, improved livelihoods and market opportunities in the Near East and North Africa

IPGRI (International Plant Genetic Resources Institute)
- ICARDA hosts and services the IPGRI Regional Office for Central and West Asia and North Africa (IPGRI-CWANA)
- ICARDA participates with other CG Centers in the Systemwide Genetic Resources Program, coordinated by IPGRI, in both plant and animal genetic resources
- IPGRI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA
- ICARDA collaborates with IPGRI in two sub-regional networks on genetic resources (WANANET and CATN/PGR).
- ICARDA participates in development of the SINGER project

coordinated by IPGRI and contributes data to the core SINGER database

- IPGRI-CWANA is a partner with ICARDA in the GEF/UNDP project on "Conservation and sustainable use of dryland agro-biodiversity in Jordan, Lebanon, Palestinian Authority and Syria"

IRRI (International Rice Research Institute)

- IRRI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA
- ICARDA is participating in the Generation Challenge Program (Unlocking Genetic Resources in Crops for the Resource Poor), led by IRRI and CIMMYT
- IRRI is the Managing Center of ICARDA's projects in Iran and Eritrea within Theme 1 on water productivity of the Challenge Programme on Water and Food
- Collaboration in the development and utilization of intelligent systems in plant protection

IWMI (International Water Management Institute)

- IWMI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA
- ICARDA is participating in the Challenge Program on Water and Food, coordinated by IWMI
- ICARDA serves on the Steering Committee of the Systemwide Initiative on the Comprehensive Assessment of Water, coordinated by IWMI.
- IWMI and ICARDA share a joint position on marginal water use
- IWMI and ICARDA are partners in a joint research project on salinity in Central Asia.
- ICARDA is participating in the CGIAR Consortium for Spatial Information - Knowledge Management Project, coordinated by IWMI

UNESCO-MAB (United Nations Education, Scientific and Cultural Organization- Man and the Biosphere Program)

- Collaboration in sustainable land management of marginal drylands

United Nations University, Tokyo, Japan

- Collaboration in sustainable land management of marginal drylands

World Vegetable Center - formerly the Asian Vegetable Research and Development Center (AVRDC)

- AVRDC participates in the CGIAR Consortium for Central Asia and the Caucasus
- Collaboration in horticulture assessment in Asia and the Near East Region

AUSTRALIA

University of Adelaide

- Plant health management for faba bean, chickpea and lentils
- Better crop germplasm, crop management and scientific training for improved production of cereals and legumes in Iraq

CLIMA (Centre for Legumes in Mediterranean Agriculture)

- Development and conservation of plant genetic resources in the Central Asian Republics.
- Preservation of the pulse and cereal genetic resources of the Vavilov Institute
- Improving crop establishment and yield of relay and post-rice-sown pulses (lentil and Lathyrus) in the cropping systems of the *terai* and mid-hills in Nepal
- Development of interspecific hybrids between chickpea and its wild relatives
- Plant health management for faba bean, chickpea and lentils
- Better crop germplasm, crop management and scientific training for improved production of cereals and legumes in Iraq

Cooperative Research Centre (CRC) for Molecular Plant Breeding

- ICARDA is a Supporting Participant (Research)
- Joint training of a PhD student (enrolled in the Southern Cross University)
- Collaborative barley breeding for low-rainfall environments
- Developing elite barley germplasm for salt-stressed environments

Cooperative Research Centre (CRC) for Grain Foods

- Genetic manipulation of pulses for improved flavor and color
- Novel barley germplasm for food and malt

Department of Primary Industry (DPI), Tamworth Centre for Crop Improvement

- Durum wheat improvement.
- Chickpea improvement

- Identification of legume viruses and selection of legume germplasm for virus disease resistance
- Plant health management for faba bean, chickpea and lentils
- Survey of faba bean diseases in Quinghai Province, China

Department of Primary Industry (DPI), Horsham, Victoria
- Coordinated improvement project on Australian lentils
- Development and conservation of plant genetic resources in the Central Asian Republics
- Plant health management for faba bean, chickpea and lentils
- Bread wheat landrace eco-geographic diversity studies

Department of Primary Industries (DPI), Victoria, Knoxfield Center
- Study the molecular variability of nanovirus and luteovirus isolates using PCR and sequence analysis

Land and Food Sciences, University of Queensland
- Collaboration in development of Laboratory Information Management System

Centre for Plant Conservation Genetics, Southern Cross University
- Development of ESTs using wild barley from ICARDA

Plant Breeding Institute, University of Sydney
- Assessment of pathogenic variation in the wheat stripe (yellow) rust pathogen.
- Breeding for resistance to barley stripe (yellow) rust

South Australia Department of Agriculture (SARDI)
- Plant health management for faba bean, chickpea and lentils

Western Australia Department of Agriculture,
- Plant health management for faba bean, chickpea and lentils
- Better crop germplasm, crop management and scientific training for improved production of cereals and legumes in Iraq

AUSTRIA

Federal Institute for Agrobiology, Linz
- Safety duplication of ICARDA's legume germplasm collection

University of Natural Resources and Applied Life Sciences, Vienna
- Production diversification in small ruminant production

BELGIUM

University of Gent
- Assessment of *Vicia sativa* and *Lathyrus sativus* for neurotoxin content

University of Leuven
- Joint supervision of MSc graduate research on integrated assessment of land degradation
- Cooperation in research on strengthening livelihood resilience in the Karkeh River Basin in Iran

CANADA

Agriculture Canada, Field Crop Development Centre, Alberta
- Development of barley germplasm with multiple disease resistance

Agriculture and Agri-Food Canada
- Collaboration in development of Laboratory Information Management System

University of Guelph, Ontario Agriculture College, Department of Plant Agriculture
- Modeling sustainability of cropping systems based on long-term trials

University of Saskatchewan, Saskatoon
- Genetic improvement of resistance to *Ascochyta* blight and Anthracnose in lentil
- Evaluation of chickpea for *Ascochyta* blight resistance
- Evaluation of chickpea germplasm and their wild relatives for resistance to vascular wilt

DENMARK

Ris□ National Laboratory, Plant Biology and Biogeochemistry Department
- Genetic mapping in barley
- Barley pathology
- Integrated cereal disease management in Eritrea

Danish Institute of Agriculture Sciences (DIAS)
- Integrated cereal disease management in Eritrea

FRANCE

CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement)
- Joint appointment of a CIRAD Research Fellow on institutional options for rangeland management

Institut National de la Recherche Agronomique (INRA)

- Morphophysiological traits associated with constraints of Mediterranean dryland conditions in durum wheat
- Water balance studies in cereal-legume rotations in semi-arid Mediterranean zone
- Collaboration on cereal cyst nematodes
- Genotyping of crop wild relatives
- Biological control and botanical pesticides against insect pests
- Studies on salt tolerance in cereals and food legumes.
- Evaluating the performance of crop model STICS developed by INRA

L'Institut de Recherche pour le Développement (IRD)

- Cooperation in the establishment of a network on water information

Université de Paris-Sud, Labo Morphogenese Vegetale Experimentale

- Production of doubled haploids in bread wheat and barley

GERMANY

University of Bonn

- QTL analysis in barley
- Integrated approaches to sustainable land management in dry areas
- Joint supervision of PhD graduate research on the use of remote sensing and GIS techniques for land degradation assessment in Syria

University of Frankfurt am Main

- Genomics of cold and drought tolerance in chickpea and lentil

University of Hamburg

- Establishment of a barley transformation system

University of Hannover

- Development of transformation protocols for chickpea and lentil
- Collaboration in research on impact assessment of natural resource management research

University of Hohenheim

- Increasing the heterozygosity level of barley to exploit heterosis under drought stress.
- Joint supervision of PhD graduate research on sustainable management of a wheat-chickpea rotation using a cropping systems simulator

University of Kiel

- Assessment of information needs for development of water management models.
- Institutions of supplemental irrigation
- Development of SSER markers in lentils

University of Leipzig

- Joint supervision of PhD graduate research on *Bedouin* families to identify constraints and opportunities for pastoral development

ITALY

Institute of Nematology, Bari

- Studies of parasitic nematodes in food legumes

Istituto Sperimentale per la Cerealicoltura, Sezione di Fiorenzuola d'Arda

- Collaboration in mapping adaptation of barley to drought environments

University of Tuscia, Viterbo.

- Diversity of storage proteins in durum wheat

University of Tuscia, Viterbo; Germplasm Institute, Bari; ENEA (Italian Research Agency for New Technologies, Energy and the Environment), Rome

- Evaluation and documentation of durum wheat genetic resources

JAPAN

Japan International Research Center for Agricultural Sciences (JIRCAS)

- Comparative genomics and cDNA microarray technology for the identification of drought and cold inducible genes in model plants
- Evaluation of genetic resources and biotechnological approaches for the improvement of wheat germplasm tolerant to environmental stresses

Kyoto University

- Collaboration in molecular characterization of wheat wild relatives

Tottori University

- Collaboration on human resource development programs for arid land sciences

REPUBLIC OF KOREA

Rural Development Administration

- Collaboration in barley research

NETHERLANDS

Wageningen University
- Collaboration on land and water management research in Syria
- Collaboration on internship on technology transfer mechanisms and participatory approaches in dry areas
- Collaboration in international training course on agrobiodiversity and support to local seed supply systems

Department of Plant Science, Laboratory of Plant Breeding, Wageningen
- Collaboration in mapping adaptation of barley to drought environments

PORTUGAL

Estacao National de Melhoramento de Plantas, Elvas
- Developing lentil, faba bean, chickpea, and forage legumes adapted to Portugal's conditions
- Evaluation of IZARIG irrigation management model for supplemental irrigation

RUSSIA

All Russian Institute of Agricultural Biotechnology, Moscow
- Establishment of barley transformation system

The N.I. Vavilov All-Russian Scientific Research Institute of Plant Genetic Resources (VIR)
- Genetic resources exchange, joint collection missions and collaboration in genetic resources evaluation and documentation
- Bread wheat eco-geographic diversity studies

SPAIN

University of Barcelona
- Durum and bread wheat stress physiology
- Barley stress physiology
- Mapping adaptation of barley to drought environments

University of the Basque Country
- Enhancing the productivity of sheep milk production systems and quality of dairy products

University of Cordoba
- Durum grain quality

UdL-IRTA (University of Lleida and Institut de Recerca i Technologia Agroalimentaria - IRTA)
- Mapping adaptation of barley to drought environments

SWITZERLAND

Station Fédérale de Recherches Agronomiques de Changins (RAC), Nyon
- Duplication of *Lathyrus* genetic resources and data

Swiss Centre for International Agriculture
- Improving resistance to barley scald

Swiss Federal Institute of Technology (ETH), Animal Nutrition Department
- Feeding systems and quality of sheep milk products

University of Bern
- World Overview of Conservation Approaches and Technologies (WOCAT)

UNITED KINGDOM

Birmingham University
- Production of *Medicago* and *Lathyrus* field guides

CABI Bioscience
- Entomopathogenic fungi for Sunn pest control

Imperial College London
- Research on microfinance

Macaulay Land Use Research Institute
- Research planning on feeding systems for small ruminant production in the dry areas
- Analysis of long-term rotational trials in sheep and fodder production

Natural Resources Institute, University of Greenwich
- Sunn pest pheromones

Scottish Crop Research Institute
- Mapping adaptation of barley to drought environments

UNITED STATES OF AMERICA

Busch Agricultural Resources Inc
- Development of barley germplasm with multiple disease resistance and enhanced malting quality

University of California, Davis
- Study of genetic diversity in natural populations of *Aegilops* spp
- Evaluation of pulse genetic resources: Collaboration in research on water productivity in Iran

- Collaboration in assessment of horticulture options

Colorado State University
- Testing for stripe rust in barley

Cornell University
- Use of molecular markers for genome mapping and marker-assisted selection for stress resistance in durum wheat

University of Delaware
- Use of information technology for improving water-use efficiency

DuPont Agric. Biotechnology
- Development of EST markers in wheat and lentils

Fort Valley State University, Georgia
- Strengthening teaching and research on sheep and goat production in Tunisia

International Nutritional Foundation
- Analysis of child nutrition among rural households

University of Hawaii:
- Collaborative training program for visiting scientists and graduate research fellows from Iraq

University of Massachusetts
- Child nutrition in rural areas of Syria

Michigan State University / IPM Collaborative Research Support program
- Integrated pest management in Central Asia

University of Minnesota:
- Research on improving productivity of oats as priority forage crops

North Carolina State University, Department of Statistical Genetics
- QTL estimation for disease data

Northern Illinois University, Division of Statistics,
- Statistical analysis of microarray data

Oklahoma State University
- Collaboration in feasibility study for sustainable renovation of *qanats* in Syria

Ohio State University
- Collaboration in research on carbon sequestration

Oregon State University
- Molecular mapping of barley within the North America Barley Genome Mapping project.
- Identification of molecular markers associated with resistance to diseases of barley

Purdue University
- GIS for watershed management in the arid regions of Tunisia

University of Missouri, Columbia
- Adaptation to drought and temperature stress in barley using molecular markers

University of Vermont
- Sunn pest biocontrol

University of Wisconsin
- Small ruminant production with emphasis in dairy sheep evaluation and crossbreeding.
- Sheep production in Central Asia

Washington State University
- Rust and *Stemphylium* blight resistance in lentil

USDA/ARS (US Department of Agriculture, Agricultural Research Service)
- Biological diversity, cultural and economic value of medicinal, herbal and aromatic plants in Tunisia and Morocco

USDA/ARS Beltsville Agricultural Research Center, Beltsville, Maryland
- Development of bread wheat cultivars facilitated by microsatellite DNA markers

USDA/ARS, Manhattan, Kansas
- Molecular genetics of Hessian fly

USDA/ARS Plant Stress and Water Conservation Laboratory, Lubbock, Texas
- Climatological analysis as a tool for agricultural decision-taking in dry areas

USDA/ARS Stillwater, Oklahoma
- Russian wheat aphid resistance and biotypes

USDA/ARS Grain Legume Genetics and Physiology Research, Pullman, Washington
- Gene mapping of economic traits to allow marker-assisted selection in chickpea
- Exploitation of existing genetic resources of food legumes
- Inheritance and mapping of rust and *Stemphylium* resistance genes in lentil

USDA/ARS Plant Science Research Unit

- Research on improving productivity of oats as priority forage crops

USDA/ARS Western Regional Plant Introduction Station, Pullman, Washington

- Conservation of temperate food, pasture and forage legume biodiversity
- Conservation and collection of plant genetic resources in Central Asia and the Caucasus

United States Wheat and Barley Scab Initiative

- Research network for the development of effective control measures that minimize the threat of *Fusarium* head blight (scab)

Yale University

- Collaboration in research on poverty, rural livelihoods and impact analysis
- Collaboration in remote sensing of rangeland degradation and vegetation analysis

Appendix 6 - Research Networks Coordinated by ICARDA

Title	Objectives/Activities	Coordinator	Countries/ Institutions	Donor Support
International & Regional Networks				
International Germplasm Testing Network	Disseminates advanced lines, parental lines and segregating populations of barley, durum wheat, bread wheat, lentil, kabuli chickpea, faba bean, vetches and chicklings developed by ICARDA, CIMMYT, and national programs. Feedback from NARS assists in developing adapted germplasm and provides a better understanding of GxE interaction and of the agroecological characteristics of major production areas.	ICARDA Germplasm Program	52 countries worldwide; CIMMYT	ICARDA Core funds
WANA Plant Genetic Resources Network (WANANET)	Working groups specify priorities in plant genetic resources; identify and implement collaborative projects; implement regional activities.	IPGRI Regional Office for CWANA; ICARDA Genetic Resources Unit	WANA countries; IPGRI; FAO; ACSAD	IPGRI, ICARDA, FAO
WANA Seed Network	Encourages stronger regional seed sector cooperation, exchange of information, regional consultations, and intercountry seed trade.	ICARDA Seed Unit	Algeria, Morocco, Iraq, Cyprus, Turkey, Jordan, Syria, Egypt, Sudan, Libya, Yemen	ICARDA
Agricultural Information Network for WANA (AINWANA)	Improve national and regional capacities in information management, preservation and dissemination.	ICARDA Communication, Documentation and Information Services	WANA countries; CIHEAM	ICARDA
The Network on Drought Management for the Near East, Mediterranean and Central Asia (NEMEDCA Drought Network)	Enhanced technical cooperation among concerned national, regional and international organizations in the Region, particularly the exchange of information and experience among the member countries, on issues concerning drought mitigation.	ICARDA serves as a Secretariat	Countries of the Near East, Mediterranean and Central Asia; FAO; EC; CIHEAM.	ICARDA, FAO, CIHEAM

Appendix 7 - Financial Information

Statement of Activity (US$x000)

	2005	2004
REVENUES		
Grants (Core and Restricted)	28,882	26,032
Other revenues and gains	932	474
Total	29,814	26,506
EXPENSES AND LOSSES		
Program related expenses	26,772	23,517
Management and general expenses	2,796	3,076
Other losses and expenses	661	44
Total expenses and losses	30,229	26,637
Indirect costs recovery	(898)	(801)
Net expenses and losses	29,331	25,836
EXCESS REVENUES OVER EXPENSES		
	483	670

Statement of Financial Position (US$x000)

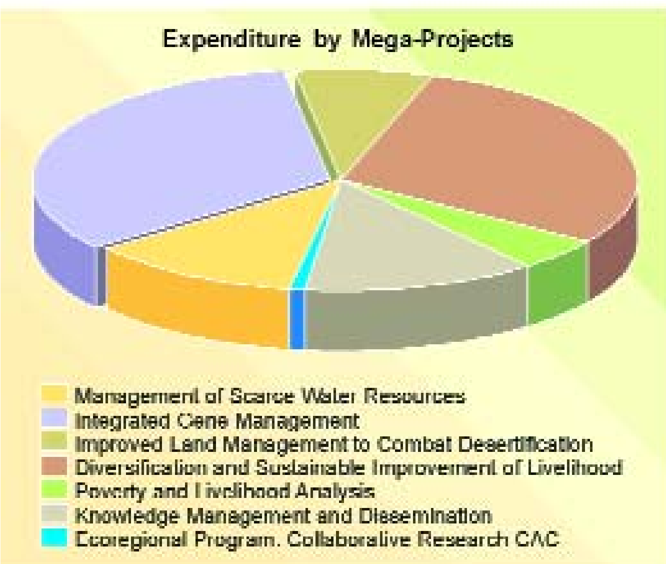
	2005	2004
ASSETS		
Current assets	28,097	26,984
Property & equipment	3,511	2,808
Total assets	31,608	29,792
LIABILITIES AND ASSETS		
Current liabilities	14,752	13,473
Long-term liabilities	4,145	4,091
Total liabilities	18,897	17,564
Net assets	12,711	12,228
Total liabilities & net assets	31,608	29,792

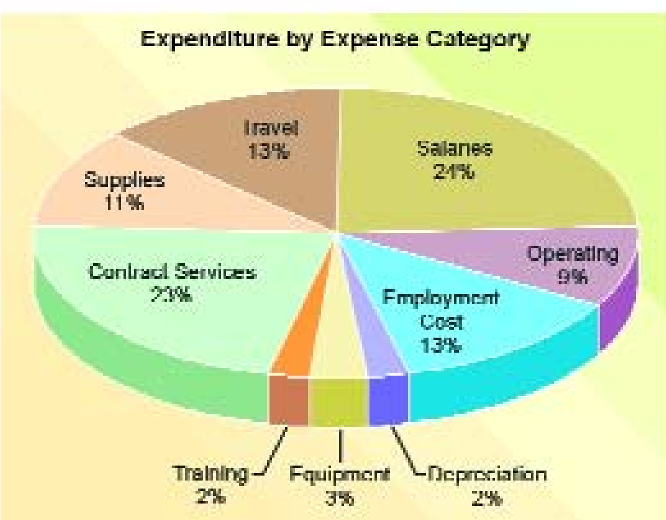
Statement of Grant Revenues 2005 (US$x000)

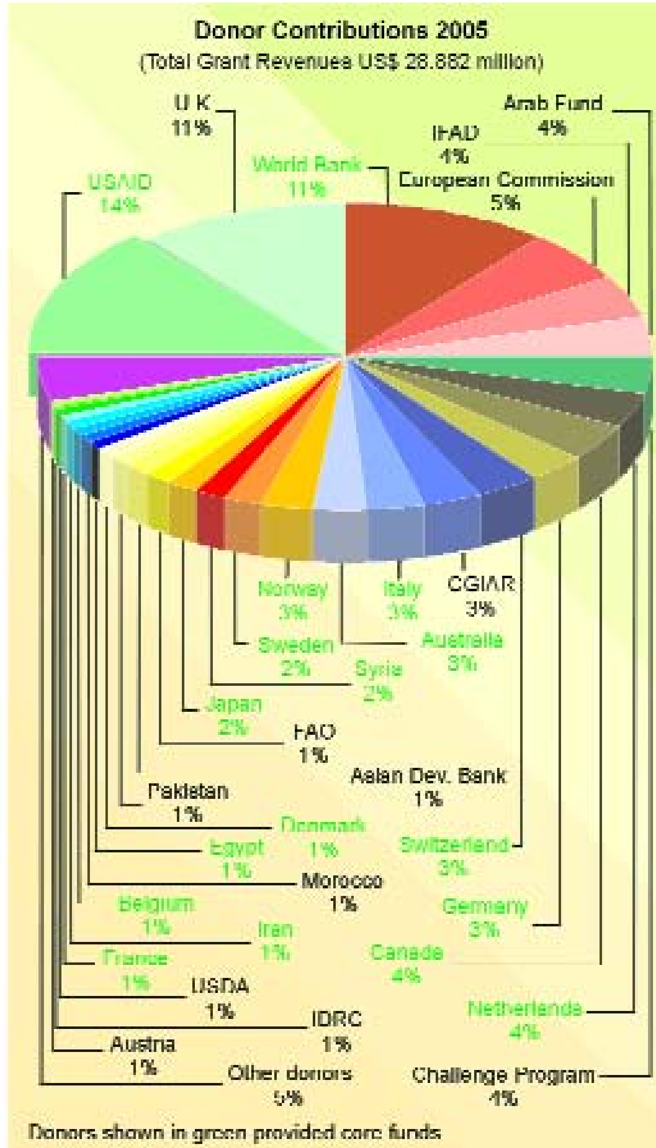
Donor	Amount
Arab Fund	1,192
Asian Dev.Bank	363
Australia*	820
Austria	146
Belgium*	230
Canada*	1,078
CGIAR	906
Challenge Program	1,107
China*	70
Denmark*	287
Egypt*	250
European Commission	1,577
FAO	416
France*	215
Germany*	933
Global crop diversity trust	108
GM-UNCCD	123
Gulf Cooperation Council	142
IDRC	151
IFAD	1,287
India*	38
INRA-INRAT	122
Iran*	217
Italy*	880
Japan*	465
JIRCAS	31
Mauritania	100
Miscellaneous	97
Morocco	240
Norway*	763
Pakistan	355
South Africa*	49
Sweden*	583
Switzerland*	931
Syria*	500
The Netherlands*	1,094
The OPEC Fund	69
Turkey	30
UNDP	132
UNEP	45
UNESCO	60
United Kingdom*	3,276
Universiy of Hawaii	108
Universiy of Minnesota	23
USAID*	3,970
USDA	181
World Bank*	3,122
TOTAL	28,882

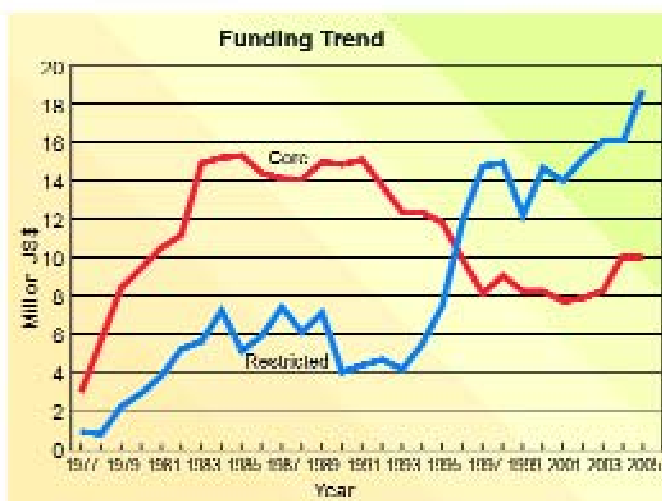
* Donors that provided core funds


Expenditure by Program and Activities
(Total Expenditure US$ 30.229 million)
Research Program
70%
Operations
5%
Administration
9%
International
Cooperation
5%
Information
2%
Training
1%
Research
Support
8%


Expenditure by Mega-Projects
Management of Scarce Water Resources
Integrated Gene Management
Improved Land Management to Combat Desertification
Diversification and Sustainable Improvement of Livelihood
Poverty and Livelihood Analysis
Knowledge Management and Dissemination
Ecoregional Program. Collaborative Research CAC


Expenditure by Expense Category
Travel
13%
Salaries
24%
Supplies
11%
Operating
9%
Contract Services
23%
Employment
Cost
13%
Training
2%
Equipment
3%
Depreciation
2%


Donor Contributions 2005
(Total Grant Revenues US$ 28.882 million)
U.K.
11%
Arab Fund
4%
IFAD
4%
World Bank
11%
European Commission
5%
USAID
14%
Norway
3%
Italy
3%
CGIAR
3%
Sweden
2%
Australia
3%
Syria
2%
Japan
2%
FAO
1%
Asian Dev. Bank
1%
Pakistan
1%
Denmark
1%
Egypt
1%
Switzerland
3%
Morocco
1%
Belgium
1%
Germany
3%
Iran
1%
Canada
4%
France
1%
USDA
1%
IDRC
1%
Netherlands
4%
Austria
1%
Other donors
5%
Challenge Program
4%
Donors shown in green provided core funds


Funding Trend
Million US$
Core
Restricted
Year
0
2
4
6
8
10
12
14
16
18
20
1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005

Appendix 8 - Board of Trustees

On 31 December 2005, the composition of ICARDA's full Board was as follows:

Dr Teresa Fogelberg
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Fax: +963 21 2225105, 2213490
E-mail: A.El-Beltagy@cgiar.org

Appendix 9 - Senior Staff (as of 31 December 2005)

Headquarters, Aleppo, Syria

Director General's Office

Prof. Dr Adel El-Beltagy, *Director General*
Dr Mohan Saxena, *Assistant Director General (At Large)**
Dr William Erskine, *Assistant Director General (Research)*
Prof. Dr Magdy Madkour, *Assistant Director General (International Cooperation)*
Dr Adel Aboul Naga, *Senior Advisor/Consultant*
Dr Elizabeth Bailey, *Project Officer*
Ms Houda Nourallah, *Administrative Officer to the Director General and Board of Trustees*

Corporate Services

Mr Michel Valat, *Director*
Mr Essam Abd Alla Saleh Abd El-Fattah, *Assistant Director*

Government Liaison

Dr Ahmed El-Ahmed, *Assistant Director General*

Finance Department

Mr Vijay Sridharan, *Director*
Mr Ahmed El-Shennawy, *Associate Director*
Mr Mohamed Samman, *Treasury Supervisor*
Mrs Imelda Silang, *Finance Officer, Budget, Donor Reporting and Outreach*

Management of Scarce Water Resources and Mitigation of Drought – Mega Project 1

Dr Theib Oweis, *Director*
Dr Adriana Bruggeman, *Agricultural Hydrology Specialist*
Dr Hamid J. Farahani, *Specialist in Irrigation and Water Management*
Dr Manzoor Qadir, *Marginal Water Management Specialist (joint appointment with IWMI)*
Dr Bogachan Benli, *Post-Doctoral Fellow - Irrigation and Water Management*
Mr Kenichi Kawakatsu, *Associate Expert**
Mr Akhtar Ali, *Water and Soil Engineer*

Integrated Gene Management – Mega Project 2

Dr Sanjaya Rajaram, *Director*
Dr Osman Abdalla El Nour, *Bread Wheat Breeder*
Dr Ali Abdel Moneim, *Forage/Legume Breeder*
Dr Michael Baum, *Biotechnologist*
Dr Mustapha El-Bouhssini, *Entomologist*
Dr Flavio Capettini, *Barley Breeder (based at CIMMYT)*
Dr Salvatore Ceccarelli, *Barley Breeder*
Dr Stefania Grando, *Barley Breeder*
Dr Rajinder Malhotra, *Senior Chickpea Breeder*
Dr Miloudi Nachit, *Durum Wheat Breeder*
Dr Ashutosh Sarker, *Lentil Breeder*
Dr Amor Yahyaoui, *Senior Cereal Pathologist*
Dr Mathew Musumbale Abang, *Junior Professional Officer*
Dr Fekadu Fufa Dinssa, *Post-Doctoral Fellow/Barley Breeder*
Mr Fadel Al-Afandi, *Research Associate*
Dr Akinnola Nathaniel Akintunde, *International Crop Information System and International Nursery Scientist*
Dr Jean Claude Chabane, *Biotechnologist*
Dr Bitore Djumahanov, *Cereal/Legume Breeder (CAC region)*
Dr Bassam Bayaa, *Senior Consultant /Legume Pathologist*
Dr Shaaban Khalil, *Consultant - Faba Bean Breeeder*
Mr Berhane Lakew Awoke, *Visiting Research Fellow*
Dr Peiguo Guo, *Visiting Scientist*
Dr Masanori Inagaki, *JIRCAS Scientific Representative*
Dr Moussa Guirgis Mosaad, *Visiting Scientist*
Dr Sripada M. Udupa, *Biotechnologist*
Ms Sofia Kobakhia, *Visiting Research Fellow**
Dr Kiros Meles, *Visiting Research Fellow**

Genetic Resources Unit

Dr Jan Valkoun, *Head*
Dr Bonnie Jean Furman, *Legume Germplasm Curator*
Dr Kenneth Street, *Coordinator - CAC Projects*
Mr Jan Konopka, *Germplasm Documentation Officer*
Dr Siham Asaad, *Head of Seed Health Laboratory*
Mr Bilal Humeid, *Research Associate*

Improved Land Management to Combat Desertification – Mega Project 3

Dr Richard Thomas, *Director*
Dr James A. Tiedeman, *Range Management Scientist*
Dr Francis Turkelboom, *Soil*

* Left in 2005

Conservation/Land Management Specialist
Dr Celine Dutilly-Diane,*Socio-economist (joint appointment with CIRAD)*
Dr Ashraf Tubeileh, *Post-Doctoral Fellow (Nutrient and Water Flows in CWANA)*
Dr Hanadi Ibrahim El-Dessougi, *Post-Doctoral Fellow (Nutrient and Water Flows)*
Mr Haben Asgedom Tedla, *Research Fellow**

Diversification and Sustainable Improvement of Rural Livelihoods – Mega Project 4

Dr Colin Piggin, *Director*
Dr Luis Iniguez, *Senior Small Ruminant Scientist*
Dr Mustafa Pala, *Wheat Based Systems Agronomist*
Dr Asamoah Larbi, *Pasture and Forage Production Specialist*
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Poverty and Livelihoods Analysis – Mega Project 5

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Mr Awad Awad, *Database Administrator and Financial Systems Senior Analyst*
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Mr Robert Thompson, *Head*
Dr Thomas Taylor, *School Head**

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Mr Tarif Kayyali, *Legal Advisor (Aleppo)*
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Appendix 10 - Acronyms

AARINENA	Association of Agricultural Research Institutions in the Near East and North Africa
ACIAR	Australian Centre for International Agricultural Research, Australia
ACSAD	Arab Center for Studies of the Arid Zones and Dry Lands, Syria
ADB	Asian Development Bank, Philippines
AfDB	African Development Bank
AFESD	Arab Fund for Economic and Social Development, Kuwait
AGERI	Agricultural Genetic Engineering Institute (Egypt)
AREO	Agricultural Research and Education Organization, Iran
AGERI	Agricultural Genetic Engineering Research Institute, Egypt
AOAD	Arab Organization for Agricultural Development, Sudan
APRP	Arabian Peninsula Regional Program
AVRDC	Asian Vegetable Research and Development Center (World Vegetable Center)
BMZ	Federal Ministry for Economic Cooperation (Germany)
CAC	Central Asia and the Caucasus
CACAARI	Central Asia and the Caucasus Association of Agricultural research Institutions
CACRP	Central Asia and the Caucasus Regional Program
CATCN	Central Asian and Trans-Caucasian Network
CGIAR	Consultative Group on International Agricultural Research
CIDA	Canadian International devel-opment Agency
CIHEAM	Centre International de Hautes Etudes Agronomiques Mediterraneennes, France
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico
CIAT	Centro Internacional de Agricultura Tropical, Colombia
CIP	International Potato Center, Peru
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France
CLAES	Central Laboratory for Agricultural Expert Systems, Egypt
CLIMA	Centre for Legumes in Mediterranean Agriculture, Australia
CNRADA	Centre National de Recherche Agronomique et de dévoloppement Agricole, Mauritania
CWANA	Central and West Asia and North Africa
DARI	Dryland Agricultural Research Institute, Iran
DACAAR	The Danish Committee for Aid to Afghan Refugees
DFID	Department for International Development, UK
ERF-FEMISE	Economic Research Forum-Euro-Mediterranean Forum of Economic Institutes
EMBRAPA	Brazilian Agricultural Research Corporation
ESCWA	Economic and Social Commission for Western Asia
EARO	Ethiopian Agricultural Research Organization
FAO	Food and Agriculture Organization of the United Nations, Italy
FHCRAA	Future Harvest Consortium to Rebuild Agriculture in Afghanistan
GAP	Southeastern Anatolia Project, Turkey
GEF	Global Environment Facility
GEF/UNDP	Global Environment Facility/United Nations Development Programme
GFAR	Global Forum on Agricultural Research
GIS	Geographic Information Systems
GOSM	General Organization for Seed Multiplication, Syria
GTZ	German Technical Cooperation Agency

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
IDRC	International Development Research Centre, Canada
IFAD	International Fund for Agricultural Development, Italy
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute, USA
IITA	International Institute for Tropical Agriculture, Nigeria
ILRI	International Livestock Research Institute, Kenya
INAT	Tunisian National Institute for Agronomy
INCO-MED	International Cooperation with Mediterranean Partner Countries (European Union)
INRA	Institut National de la Recherche Agronomique, France
INRAT	National Agricultural Research Institute of Tunisia
IPGRI	International Plant Genetic Resources Institute, Italy
IPM	Integrated Pest Management
IRDEN	Regional Program to Foster Wider Adoption of Low-cost Durum Technologies
IRESA	Institution de la Recherche et de l'Enseignement Superieur Agricoles, Tunisia
IRRI	International Rice Research Institute, Philippines
IWMI	International Water Management Institute, Sri Lanka
IWWIP	International Winter Wheat Improvement Project
JICA	Japan International Cooperative Agency, Japan
JIRCAS	Japan International Research Center for Agricultural Sciences
LARI	Lebanese Agricultural Research Institute, Lebanon
MAWR	Ministry of Agriculture and Water Resources, Uzbekistan
M&M	Mashreq and Maghreb
MRMP	Matrouh Research Management Project, Egypt
NARP	North Africa Regional Program
NARS	National Agricultural Research Systems
NASA	National Aeronautics and Space Administration, USA
NCARTT	National Center for Agricultural Research and Technology Transfer, Jordan
NGO	Non-Governmental Organizations
NVRSRP	Nile Valley and Red Sea Regional Program
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries, Austria
PPDRI	Plant Pests and Diseases Research Institute, Iran
SC	Science Council of the CGIAR
SPIA	Standing Panel on Impact Assessment
SPII	Seed and Plant Improvement Institute, Iran
SDC	Swiss Agency for Development and Cooperation, Switzerland
TAGEM	Tarimsal Arastirmalar Genel Mudurlugu (Turkey)
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
UNU	United Nations University, Japan
UN/WFP	United Nations/World Food Programme
UPOV	International Union for the Protection of New Varieties of Plants, Switzerland
USAID	United States Agency for International Development, USA
USDA	United States Department of Agriculture, USA
WANA	West Asia and North Africa
WARP	West Asia Regional Program, Jordan

Appendix 11 - ICARDA Addresses

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