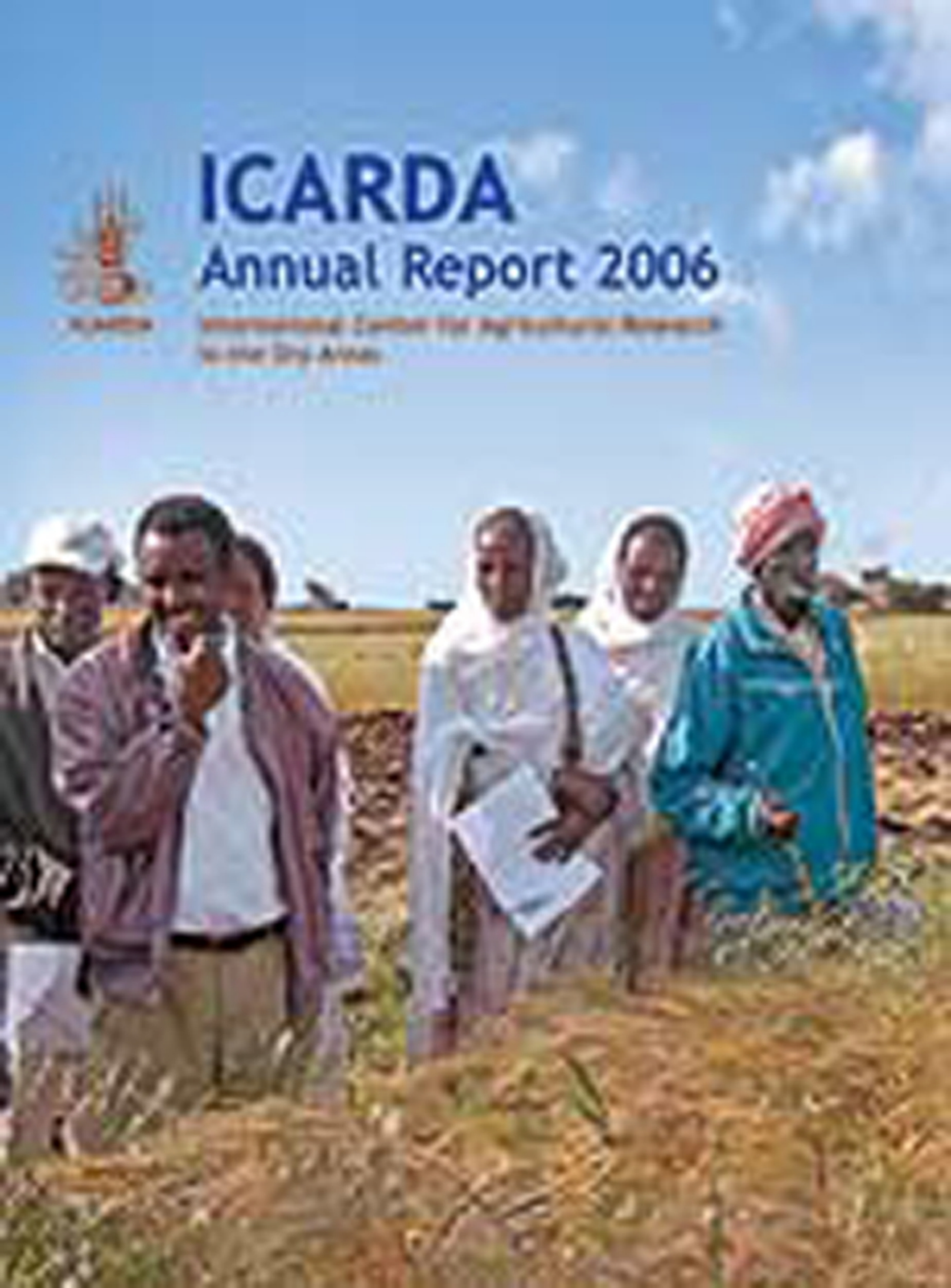
ICARDA
Annual Report 2006



ICARDA
Annual Report
2006

ICARDA

International Center for Agricultural Research in the Dry Areas

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Foreword

ICARDA witnessed several important developments in 2006. Of these, the Fifth External Program and Management Review (EPMR) was the most significant, as it provided a comprehensive assessment of the Center's global activities, as well as new insights and dimensions that helped refine ICARDA's new Strategic Plan for 2007-2016. The EPMR coincided with a transition in the governance and leadership of ICARDA. Against the backdrop of the EPMR recommendations, the staff, management and Board of Trustees took a fresh look at the Center's achievements and lessons learned since it was established. Areas in need of strategic realignment were identified to reposition ICARDA to meet the emerging challenges driven by climate variability and change, population growth, globalization, and other factors in dry areas.

The EPMR report highlighted the very positive feedback from ICARDA's stakeholders, commended the quality and relevance of the Center's research, the sound financial management, the strength of regional programs, the Center's strong relationships with NARS partners; and acknowledged that ICARDA activities have had significant impact on improving agricultural productivity and livelihoods in the dry areas. Implementation of the EPMR recommendations started in 2006.

During the year, ICARDA continued to make rapid strides in its research and training activities. The Center ranked "Superior" in the CGIAR Annual Performance Measurement for 2006, based on a set of performance indicators, and was highest among the 15 sister centers for its commitment to documenting impacts and building an impact assessment culture of its research. Eighteen improved varieties of wheat, barley, chickpea, lentil, grass pea and faba bean, developed jointly by NARS-ICARDA teams from ICARDA-generated germplasm material, were released in 11 countries. Adoption of the varieties released earlier, and of improved technologies for water, land and livestock management, continued to increase and was documented through socioeconomic and impact studies. New, strategic partnerships were forged to increase ICARDA's efforts on crop diversification, particularly high-value crops and value-added crop and livestock products. In this context, studies on characterization of indigenous small-ruminant breeds were published to help national researchers exploit the genetic potential of different breeds available in the region.

Work at the water benchmark sites, aimed at improving water-use efficiency, made substantial progress in bringing local communities, policy makers and national researchers together: the number of farmers using micro-catchment water harvesting systems to capture rainfall in the steppe areas of Jordan has tripled; the terraced-furrows system, which uses 30% less water, gained popularity in the irrigated benchmark area in Egypt; and early sowing and supplemental irrigation attracted increased farmer attention in the rainfed benchmark area in Morocco.

In order to leverage its international presence and encourage wider dissemination of the International Public Goods produced through its research, ICARDA scaled up its participation in various international conventions, particularly the United Nations Convention to Combat Desertification (UNCCD). ICARDA, together with ICRISAT, continued to lead the Oasis Consortium to combat desertification, working with nine other CGIAR Centers and a number of national governments, research centers and other partners. Among several initiatives of the Center to contribute to the "International Year of Deserts," the most significant was an international conference, which ICARDA co-sponsored with the International Drylands Development Commission, Chinese Academy of Sciences, United Nations University, Tokyo, and other partners. The conference was held in Beijing, China, in February 2006.

The Center continued to contribute to the rebuilding of agricultural research and human resources expertise in countries affected by war and conflict in the region, particularly Afghanistan, Iraq and the Palestinian Authority. Donor support for these efforts continued to be strong, enabling the Center and its partners to scale up their efforts, with great success in strengthening agricultural research capacity to support national economic development.

ICARDA is indebted to Dr Margaret Catley-Carlson and Prof. Dr Adel El-Beltagy, who held the office of the Board Chair and Director General, respectively, until 7 May 2006, for their vision and able governance and leadership of the Center. Their contributions to the growth and development of ICARDA are gratefully acknowledged.

The achievements reported in this Annual Report would not have been possible without the generous support of a large number of donors to the Center (listed in Appendix 7). ICARDA is grateful to all of them. The Center looks forward to continue working with a sharper focus on alleviating poverty and protecting the natural resource base, using modern tools of science, in collaboration with its partners in dry areas globally.

Guido Gryseels
Chair, Board of Trustees

Mahmoud Solh
Director General

Highlights of the Year

Change of Guard

The year 2006 marked a transition in the governance and leadership of ICARDA. The transition took place on the Center's Presentation Day, held on 7 May and attended by several ministers, ambassadors and other senior diplomats, donor representatives, leaders of national agricultural research systems, former ICARDA Board Chairs and Members, former ICARDA Directors General, and media representatives.

Dr Margaret Catley-Carlson formally handed over the office of Board Chair to Dr Guido Gryseels. "Guido has a wealth of knowledge of the CGIAR System – his wide leadership experience in non-profit research and development sectors makes him an ideal candidate to serve in this position," she said.

Dr Margaret Catley-Carlson handed over the office of Board Chair to Dr Guido Gryseels (right). Dr Catley-Carlson served on the ICARDA Board from April 2001 to May 2006. Dr Gryseels joined the Board in 2003. He is the Director General of the Royal Museum for Central Africa in Belgium.

In his farewell address, Prof. Dr Adel El-Beltagy, outgoing Director General, spoke of ICARDA's achievements in the past decade, and his optimism for the future.

Dr Mahmoud Solh, incoming Director General, highlighted the areas that would receive priority.

Dr Gryseels joined ICARDA's Board of Trustees in 2003. Until he took over as Board Chair, he had been serving as a member of the Executive, Nomination and Program Committees of the Board.

The distinguished audience at ICARDA's Presentation Day, held on 7 May 2006.

Highlights of the Year

Thanking the Board of Trustees and management of ICARDA for their trust in him, Dr Gryseels said he was committed to ICARDA's mission of alleviating poverty and hunger in dry areas of the developing world, and that he looked forward to further contributing to this mission by working with ICARDA and its partners.

On behalf of the management and staff of ICARDA, Prof. Dr Adel El-Beltagy (outgoing Director General) paid tribute to Dr Catley-Carlson for her leadership of the Board of Trustees. "Maggie is a wonderful diplomat, has enormous capacity to absorb knowledge and transmit it, and has held several positions of responsibility including her current position as Chair, Global Water Partnership," he said. He thanked her for taking excellent care of the Center and its staff, and for her active role in fund raising.

Dr Mohamed Zehni, Vice-Chair of the Board, said, "Maggie is endowed with great experience, knowledge, and wisdom. Her human qualities of friendship and her love for the region and its people are all unparalleled."

Dr Catley-Carlson thanked everyone for their support to her. She thanked all those who have been supporting ICARDA, noting that more than 10% of ICARDA's revenue now comes from donors within the region.

The Presentation Day also marked a transition of the Director General from Prof. Dr Adel El-Beltagy to Dr Mahmoud Solh. Paying tribute to Prof. Dr El-Beltagy, who was retiring after having served the Center for more than 11 years, Dr Catley-Carlson said, "Of all the extraordinary things I will remember when I think about your contribution, I think I will most remember your skill in putting together a global network of people and institutions that really care about changing the outlook for those in dry areas. With your special magic, you turned that into a network of friends who laughed together, studied together, talked together and worked together. Thank you Adel for your immense contribution to ICARDA, for the quality of caring you brought to the Center's beautiful headquarters at Tel Hadya, and for your passionate conviction that life can be better for those in the world's dryland areas."

Responding to the tributes paid to him, Prof. Dr El-Beltagy said, "I am overwhelmed by your generosity. I have done nothing more than what I should have done, and indeed I should have done more." He thanked everyone for their support to him and to ICARDA. He thanked the past and present Board Chairs and Members and the former DGs for leading ICARDA to become a dynamic and forward-looking Center. He concluded by urging everyone present to contribute to peace and stability in the world.

Dr Catley-Carlson then introduced Dr Mahmoud Solh as the new Director General. Welcoming Dr Solh, Dr Catley-Carlson said: "Dr Solh is no stranger to ICARDA and therefore I hardly need to introduce him to you. Being a Lebanese, he is a son of the soil, knowing the ICARDA region and its challenges well. He has been associated with international agricultural research and development in the dry areas since 1972 when he joined the Arid Land Agricultural Development (ALAD) Program in the Near East, the predecessor of ICARDA."

Dr Solh returns to ICARDA after serving as Director of the Plant Production and Protection Division at the Food and Agriculture Organization of the United Nations (FAO) for four years. Prior to that he had served ICARDA with distinction for nearly 16 years in various capacities – as Lentil Breeder, Regional Food Legume Breeder in North Africa, Regional Coordinator of the Nile Valley and Red Sea Regional Program, and Assistant Director General for International Cooperation.

Responding to Dr Catley-Carlson and addressing the Presentation Day guests, Dr Solh said, "I would like to thank the ICARDA Board of Trustees for their highly-valued confidence placed in me to fill this position. I would also like to express my appreciation to H.E. Dr Adel Safar, Minister of Agriculture and Agrarian Reform, Syria, for his encouragement and continued support to ICARDA and to me personally. Through him, I would like to convey my special thanks to H.E. Dr Bashar Al-Assad, President of Syria, and his government, for their unwavering support to ICARDA since its establishment in 1977. I sincerely hope to be up to the expectations of all stakeholders in meeting the challenges facing ICARDA to contribute effectively to agricultural research and provide quality science and technology necessary for the development of dry areas globally.

"The success of ICARDA in achieving its noble mission of alleviating poverty and hunger depends on the support of all stakeholders. The challenges of agriculture in the harsh environments of dry areas are diverse, and these can only be addressed effectively through strategic partnerships."

Farewell to Departing Board Members

At a dinner reception hosted in honor of the Presentation Day guests on 6 May, Dr Catley-Carlson and Prof. El-Beltagy paid tribute to the following Board Members, who were completing their tenure, for their significant contributions to the growth and development of ICARDA: Dr Gareyth Wyn Jones (U.K.), outgoing Chair, Program Committee and Member, Executive Committee; Dr Seyfu Ketema (Ethiopia), outgoing Vice-Chair, Program Committee and Member, Nomination Committee; Dr Abbas Keshavarz (Iran), outgoing Chair, Nomination Committee and Member, Executive and Program Committees; and Dr Mohamed Bassam Al-Sibai (Syria), outgoing Member, Audit, Program and Executive Committees. Dr Catley-Carlson and Prof. El-Beltagy welcomed two new members to the Board: Dr Henri Carsalade (France), Member, Program Committee; and Prof. (Ms) Aigul Abugalieva (Kazakhstan), in absentia, Member, Program Committee.

Robert Havener Memorial Lecture Series Launched

At a dinner reception for the Presentation Day guests on 6 May, ICARDA launched the "Robert Havener Memorial Lecture" series. Dr Ismail Serageldin, Director, Bibliotheca Alexandrina, Egypt, and former Chair of the CGIAR, delivered the first lecture entitled "From Glorious Past to Brilliant Future: Ten Commandments for Global Agriculture." The lecture was much appreciated by the audience.

Dr Ismail Serageldin delivering the first Robert Havener Memorial Lecture.

Dr Robert (Bob) D. Havener, former Board Chair of ICARDA, passed away on 3 August 2005. He also provided leadership and guidance to other CGIAR centers and international organizations in various capacities with great distinction.

ICARDA Rated 'Superior' in CGIAR Evaluation

ICARDA was rated 'Superior', following a CGIAR evaluation of the 2006 performance of all 15 CGIAR Centers. The rating was based on the results of the performance measurement system developed by the CGIAR and the World Bank, which considered several indicators: research outputs, impact, quality and relevance of research, institutional and financial health, and stakeholder perceptions of each Center's contributions. Also, ICARDA was ranked highest among all CGIAR Centers for its commitment to documenting impacts and building an impact assessment culture of research.

Fifth External Program and Management Review of ICARDA

The Fifth External Program and Management Review (EPMR) of ICARDA took place in two phases: 22-28 April and 10-24 June 2006. Between the two phases, the Panel members visited the Center's collaborative research activities with national partners in several countries in the Central and West Asia and North Africa (CWANA) region.

Chaired by Prof. Dr Elias Fereres, Professor of Agronomy at the University of Cordoba, and Researcher at the Institute of Sustainable Agriculture, Scientific Research Council of Spain (IAS-

Dr Elias Fereres (center), EPMR Panel Chair, presented the Panel recommendations to the management and staff of ICARDA on 22 June. With him are Dr Guido Gryseels (left), Board Chair, and Dr Mahmoud Solh, Director General of ICARDA.

CSIC), the Panel consisted of the following members: Prof. Dr Stephen Baezinger, University of Nebraska, Lincoln; Prof. Dr Ahmed Goueli, Secretary General of the Council of the Arab Economic Unity and Professor of Agricultural Economics, Cairo University; Dr John Passioura, Division of Plant Industry, Canberra; and Dr Juliet McKee, an economist based in Wellington, New Zealand. The Panel was assisted by two consultants: Dr Camilla Toulmin, Director, Drylands Program, International Institute for Environment & Development (IIED), London; and Mr Frederick Kalema-Musoke, a financial analyst. There were also two resource persons from the Science Council: Dr Peter Gardiner, Senior Officer; and Ms Jenny Nasr, Agricultural Research Officer.

Dr Fereres presented a preliminary report and recommendations of the Panel to ICARDA management and senior staff on 22 June 2006.

The EPMR Panel with ICARDA senior management and scientists. Front row (left to right): Mr Frederick Kalema-Musoke, Consultant to EPMR Panel; Prof. Dr Stephen Baezinger, Panel member; Prof. Dr Adel El-Beltagy, ICARDA Director General; Dr Juliet McKee, Panel member; Prof. Dr Elias Fereres, Panel Chair; Ms Jenny Nasr, from the Science Council Secretariat. Back row: Dr John Passioura (far right), Panel member; and Dr Peter Gardiner (third right), from the Science Council Secretariat.

Eighth International Conference on Dryland Development

The International Dryland Development Commission (IDDC) held its 8th International Conference on Dryland Development (ICDD) under the theme "Human and Nature – Working Together for Sustainable Development in the Drylands" in Beijing, China, 25-28 February 2006. The conference was hosted by the Chinese Academy of Sciences (CAS), and cosponsored by the United Nations University (UNU), Tokyo, Japan; Arid Land Research Center (ALRC), Tottori, Japan; Dryland Research Institute (DRI), Nevada, USA; and Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI), Lanzhou, China. The AAAID, CAS, CGIAR, COMSTECH, FAO and ICARDA supported the Commission in organizing the conference. Some 200 delegates from 26 countries and five international organizations participated in the conference.

Prof. Dr Adel El-Beltagy, President of the IDDC and Director General of ICARDA, chaired the inaugural session.

Academician Prof. Dr Li Jiayang, Vice President of CAS, was the chief guest.

The 8th ICDD was the first major event heralding the beginning of the UN Year of Deserts, said Prof. El-Beltagy. He thanked the Chinese Academy of Sciences for hosting the conference in Beijing. On behalf of the cosponsors, statements were made by Prof. Dr Iwao Kobori from UNU, representing Prof. Dr Hans van Ginkel, Rector, UNU; Dr Noureddin Mona, FAO's Resident Representative for China, Korea and Mongolia; Prof. Dr Stephen Wells, Director of DRI; and Prof. Dr Wang Tao, Director of CAREERI. A statement on behalf of the Chairman of the CGIAR, Dr Ian Johnson, Vice-President of the World Bank, expressing his strong support for the conference and wishing the participants success, was read by Dr Mohan Saxena, Executive Secretary of the IDDC.

Academician Prof. Dr Li Jiayang, in his inaugural address, congratulated the IDDC for holding its 8th ICDD at the beginning of the UN Year of Deserts. He underpinned the importance of the development of dry areas for global food security and for sustaining the livelihood of people in the developing world.

The conference included three plenary sessions involving 12 presentations; and seven concurrent sessions, where 115 oral presentations were made on 10 different themes. In addition, there were three poster sessions in which 35 posters were presented.

Prof. Dr Adel El-Beltagy (fourth from left), President of the IDDC and Director General of ICARDA, chaired the inaugural session. Academician Prof. Dr Li Jiayang (fifth from left), Vice President of CAS, was the chief guest. Seated from left to right: Prof. Wang Tao, CAS; Prof. Stephen Wells, DRI, USA; Dr Noureddin Mona, FAO; Prof. Dr Adel El-Beltagy; Prof. Dr Li Jiayang; Prof. Dr Iwao Kobori, UNU; Dr Mohan Saxena, Executive Secretary, IDDC; and Prof. Dr Shinobou Inanaga, JIRCAS, Japan.

CWANA-Plus – a New South-South Partnership

During the conference, at a special plenary session, ICARDA and UNU announced the launching of a new south-south partnership "CWANA-Plus." The objectives of this joint initiative include sharing expertise and facilities, training developing-country scientists, providing opportunities for a Masters' degree program in integrated land management, and promoting best practices across the vast CWANA region and neighboring dry areas in Western China, South Asia, and sub-Saharan Africa.

CWANA-Plus will use the long experience and existing networks of UNU and ICARDA to link centers of excellence in research and capacity building, identify gaps in research and technology transfer, and select appropriate partners to reach out to the poor who stand in need of support to fight desertification and protect their livelihoods.

ICARDA-CIMMYT Partnership: The Global Rust Initiative

The Global Rust Initiative (GRI) held its first workshop on 9-11 October at the Bibliotheca Alexandrina in Alexandria, Egypt. The GRI is an international R&D consortium led by ICARDA and CIMMYT, in partnership with the NARS of over 30 countries. It was launched in September 2005, following the disastrous outbreak of a new strain of wheat stem rust, Ug99, first identified in Uganda in 1999. GRI is currently supported by USAID, Canada and India.

Wheat stem rust, caused by the fungus *Puccinia graminis*, caused huge losses and even famines in the first half of the 20th century. In 1950 it destroyed nearly 70% of wheat plantations in North America. The latest outbreak caused heavy losses in East Africa; small-scale farmers in Kenya lost half their crop. Scientists fear the disease could spread to the Middle East, Asia and the Americas, because the pathogen spores can be trans-

Dr Abdelsalam Gomaa (second left), representing the Minister of Agriculture and Land Reclamation, Egypt, inaugurated the GRI meeting. Dr Mahmoud Solh (left), Director General of ICARDA; Dr Masa Iwanaga (second right), Director General of CIMMYT; and Dr Scott Christiansen, USAID representative, made opening statements.

ported over long distances by wind.

Dr Abdelsalam Gomaa, representing the Minister of Agriculture and Land Reclamation, Egypt, inaugurated the meeting. In their opening statements, Dr Mahmoud Solh, ICARDA Director General and Dr Masa Iwanaga, CIMMYT Director General, emphasized the importance of partnerships in controlling wheat stem rust. "The risk of a stem rust epidemic in wheat in Africa, Asia and the Americas is real, and must be averted before untold damage and human suffering is caused," said Dr Solh. ICARDA, CIMMYT, USDA-ARS, Agriculture and Agri-Foods Canada, the Indian Council of Agricultural Research, the Kenya Agricultural Research Institute and the Ethiopian Agricultural Research Organization are already actively involved in the GRI. CIDA, FAO, USAID and the World Bank are now fully aware of the potential threat from Ug99. Strong links with all the NARS in the CWANA region already exist.

The workshop was attended by 56 participants from 21 countries.

Participants agreed to carry out field surveys in all threatened countries, identify genetic resources with resistance to stem rust, develop new resistant varieties, identify suitable fungicides and methods for their optimal use, multiply seed of resistant varieties, and develop NARS capacity in rust research.

Participants of the First Workshop of the Global Rust Initiative, held in Alexandria, Egypt, 9-11 October.

Director General of OPEC Fund Visits ICARDA

H.E. Suleiman J. Al-Herbish, Director General of the OPEC Fund for International Development (OFID), visited ICARDA on 22–23 June. He was accompanied by Mrs Ikhlass Najib, Head of the Grants Unit, OFID. The objective of the visit was to obtain first-hand information on ICARDA's programs and facilities, and discuss the Center's ongoing and future collaboration with OFID.

Dr Mahmoud Solh, Director General, briefed the visitors on the Center's activities. After the briefing, H.E. Al-Herbish addressed ICARDA's senior management and scientific staff.

OFID was the first donor to come forward with a US$4 million support to ICARDA in 1980 for the construction of its new headquarters buildings. This funding helped ICARDA construct its Lab 1 and Lab 2, which have been serving not only ICARDA scientists but also a large number of trainees and graduate students. OFID has also supported ICARDA's research programs in cereal improvement, participatory barley breeding, natural resource management, wind erosion, community-based seed production in

H.E. Suleiman Al-Herbish and Dr Mahmoud Solh at the entrance of Lab 1. The plaque in the background is inscribed with ICARDA's acknowledgment of OFID's support to construct Lab 1 and Lab 2 buildings.

Afghanistan, livestock improvement (jointly with ILRI), the Arabian Peninsula Regional Program (jointly with IFAD and the Arab Fund), and sustainable management of scarce water resources in WANA.

H.E. Al-Herbish then presented an overview of OFID's programs and objectives. OFID has provided grants and aid for a variety of projects and activities in developing countries, including assistance to member countries following natural disasters. The Fund contributes actively to HIV/AIDS interventions, in collaboration with UNESCO, WHO, and other organizations. He assured that the Fund would continue to support ICARDA's programs in the future.

Honors and Awards

Prof. Dr Adel El-Beltagy, ICARDA Director General (until 7 May) was elected Chair of the Global Forum on Agricultural Research, and a Fellow of the Academy of Sciences for the Developing Countries.

Dr Raj Paroda, Regional Coordinator, ICARDA-CAC and Head, PFU-CGIAR, received a gold medal and a certificate from the Government of Armenia in recognition of "the outstanding contribution of the CGIAR Consortium in CAC towards the development of sustainable agriculture in Armenia."

Dr John Ryan, Consultant Soil Fertility Scientist, won the 2006 International Fertilizer Association Award. He was also re-elected as Chairman of Commission 3.3 (Soil Fertility and Plant Nutrition) of the International Union of Soil Sciences.

Dr R.S. Malhotra, Senior Chickpea Breeder, received an honorary doctorate degree in agricultural science from the Tajik Academy of Agricultural Sciences, Tajikistan; and an honorary professorship from the Gulistan State University, Uzbekistan.

Dr Mustapha El Bouhssini, Entomologist, was appointed as an Adjunct Faculty Member in the Department of Entomology at Kansas State University, USA.

Dr Jan Valkoun, Head of Genetic Resources Unit, received an award from CIMMYT for his contributions to world wheat conservation and utilization.

Dr Ahmed Amri, Regional Coordinator, West Asia Regional Program; Dr Theib Oweis, Director, Management of Scarce Water Resources and Mitigation of Drought; and Dr Salvatore Ceccarelli, Barley Breeder, received awards from the Government of Jordan for their contributions to strengthening partnership between Jordan and ICARDA.

Dr Khaled Makkouk, Regional Coordinator, Nile Valley and Red Sea Regional Program, was

H.E. Suleiman Al-Herbish (third right, front row), Director General of OFID; Mrs Ikhlass Najib (second right, front row), Director of the Grants Unit, OFID; and Ms Rana Naimeh (third left) of OFID, with ICARDA Director General Dr Mahmoud Solh (center, front row) and other senior staff of the Center.

Highlights of the Year

elected President of the Mediterranean Phytopathological Union for a 3-year term.

ICARDA's collaborative research on integrated management of Sunn pest in West and Central Asia won the CGIAR Award for Innovative Partnership. Dr Mustapha El-Bouhssini, ICARDA entomologist, and Drs Bruce Parker and Margaret Skinner, from the University of Vermont, who have been leading the partnership for over a decade in collaboration with scientists from national agricultural research systems (NARS) as well as specialists worldwide, received the award.

A poster on "Protected Agriculture in Yemen: More Income for Farmers from Less Water" by Dr Ahmed Moustafa, Regional Coordinator, Arabian Peninsula Regional Program; and Abdul Wahed Mukred, Amin Al-Kirshi, Mohammad Al-Sadi and Mohammad Al-Dhubani of the Agricultural Research and Extension Authority, Yemen, won the best poster award at the Second Triennial Conference of the Global Forum on Agricultural Research.

Dr Mohammed El Mourid, Regional Coordinator of ICARDA's North Africa Regional Program, was honored by the Ministry of Scientific Research, Technology and Capacity Building of Tunisia for his contribution to science and technology in Tunisia.

Varieties Released in 2006

Variety	Country of release	Features
Barley		
Moronera INIA	Peru	Resistant to rust; adapted to high elevation, shallow soils; grain quality for processing
INIA 411 San Cristobal	Peru	Resistant to yellow rust, moderately resistant to leaf rust
Faba bean		
Wadi-1	Egypt	Early maturity, high yield, adapted to intensive cropping
Gebelcho	Ethiopia	Large seeded
Moti	Ethiopia	Large seeded
Lentil		
Cagil	Turkey	Wilt-resistant red lentil, suitable for mechanized harvesting
Altin toprak	Turkey	Wilt-resistant red lentil, suitable for mechanized harvesting
VL Masoor 507	India	Bold seeded, good wilt resistance
Masoor 2006	Pakistan	High yield red lentil, resistant to rust and wilt complex
BARI Masur-5	Bangladesh	Combined resistance to rust and *Stemphylium* blight, suitable for mix- and intercropping
BARI Masur-6	Bangladesh	Combined resistance to rust and *Stemphylium* blight, suitable for mix- and intercropping
Winter and facultative wheat*		
Armcim	Armenia	High yield, resistance to yellow rust
Gobustan	Azerbaijan	High yield, resistance to yellow rust
Chickpea		
Ejere	Ethiopia	Wilt-resistant, bold-seeded kabuli
Teji	Ethiopia	Wilt-resistant, bold-seeded kabuli
Grass pea (*Lathyrus*)		
Ali Bar	Kazakhstan	High yield, low neurotoxin in seed
Gürb□z	Turkey	High yield, low neurotoxin in seed
Hassyly	Turkmenistan	High yield, low neurotoxin in seed

*in collaboration with CIMMYT

ICARDA's Research Portfolio

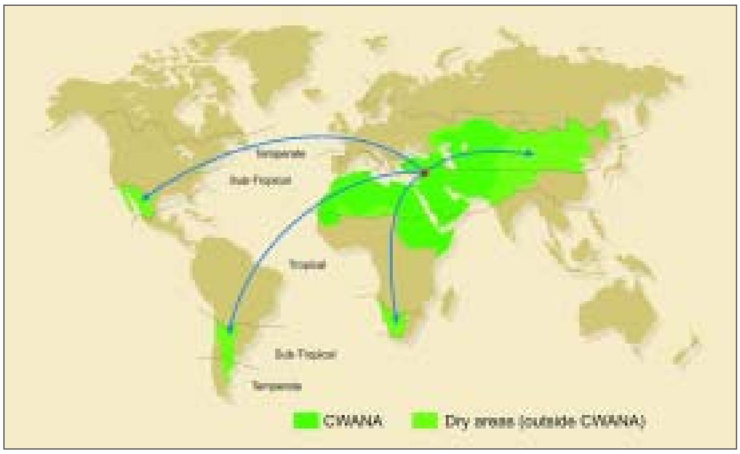
On 1 January 2005, ICARDA implemented a realigned research portfolio which consolidated its 19 research projects into six Mega-Projects (MPs). The new portfolio was designed to be a coherent poverty-focused program to address the key problems of the dry areas, optimize synergy in research, and bring to bear on the Center's collective knowledge, expertise and resources in the most effective and efficient way. 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, enhancement and sustainable use of agrobiodiversity in dry areas
Mega-Project 3: Improved land management to combat desertification
Mega-Project 4: Diversification and sustainable improvement of 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.



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 severe. 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 last 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.

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 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 research 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 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)	
					2005/06 season	Long-term average
Syria						
Tel Hadya	36.01° N	36.56° E	284	948	290.3	347.7 (28 seasons)
Breda	35.56° N	37.10° E	300	95	236.9	272.7 (26 seasons)
Lebanon						
Terbol	33.49° N	35.59° E	890	23	488.6	537.4 (26 seasons)
Kfardane	34.01° N	36.03° E	1080	11	437.9	459.2 (12 seasons)

Mega-Project 1

Management of Scarce Water Resources and Mitigation of Drought in Dry Areas

Introduction

By definition, dry areas are water scarce. Rainfall is highly variable and unpredictable, both spatially and temporally, increasing the risks and uncertainties for farming communities. The Management of Scarce Water Resources and Mitigation of Drought in Dry Areas Mega-Project (Mega-Project 1) focuses on strategic research on sustainably increasing water productivity, and has expanded its scope from the farm to the watershed and basin levels. Partnerships within the CGIAR's Challenge Program on Water and Food and with IWMI have been established to achieve a complementary approach whereby ICARDA focuses on assessing and improving on-farm water productivity and IWMI focuses on out-scaling to the basin level.

Mega-Project 1 is placing increased emphasis on the assessment of scarce water resources, including both fresh and marginal-quality water, and their sustainable allocation for 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 in national programs 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 CIHEAM.

Improved options for end-users are developed and disseminated using integrated and multidisciplinary research, and participatory approaches at the community level at selected benchmark sites. Research on policy and institutions is implemented in collaboration with Mega-Project 5 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.

Growing more food with less water in Iran's Karkheh River Basin

ICARDA is helping to coordinate a four-year project to improve water use in the Karkheh River Basin, Iran. This is part of the CGIAR's Challenge Program on Water and Food. The Karkheh Basin (Fig.1.1) is one of nine basins worldwide where the Challenge Program is working to sustainably improve the incomes and livelihoods of resource-poor communities by improving water management.

The Karkheh River Basin was chosen for two reasons. First, it is one of the most important agricultural areas in Iran. But annual rainfall is only 150 mm in the south and 750 mm in the north. A growing population and rising per capita water consumption place huge demands on the basin's limited water resources. Although the new Karkheh Dam will boost water supplies, the need to increase water productivi-

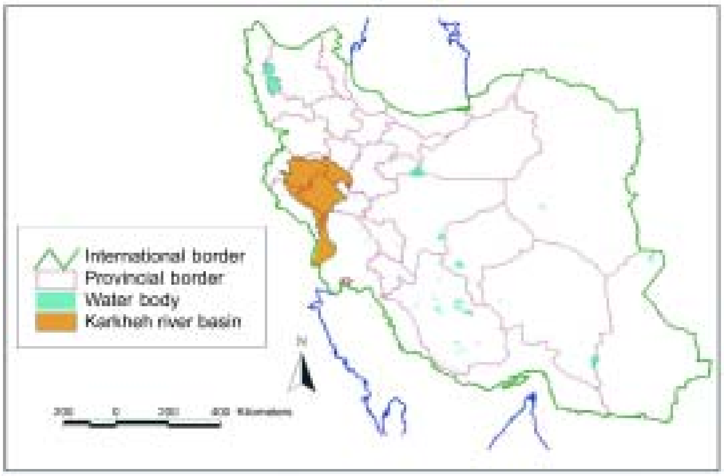


Fig. 1.1. The Karkheh River Basin in Iran.

Management of Water Resources and Mitigation of Drought

The project addresses problems such as waterlogging (left) and severe build-up of salt (right) in irrigated fields in the Karkheh Basin, Iran.

ty is so urgent that Iran has identified improving water productivity (yield per unit of water used) as a top priority in its agricultural strategy.

The second reason that the Karkheh Basin was chosen is because it is typical of basins in the arid to semi-arid Central and West Asian region. The lessons learned will therefore be adapted to other basins as far apart as the Euphrates and the Amu Darya.

To improve farm and basin-wide water productivity and the management of the natural resource base in the basin, researchers selected four sites representing both rainfed and irrigated farming. Work at these four sites focuses on:

- Identifying options to produce more crops with less water in irrigated and rainfed farming,
- Helping farmers adopt new practices and technologies that raise water productivity,
- Assessing and helping develop policies and systems for managing water effectively, and
- Helping institutions and community groups to develop skills in resolving conflicts and managing water.

Researchers, together with farmers, community leaders, local institutions, extension staff, and policy makers, take a problem-solving approach. Because everyone participates, adoption rates for new ways of managing water are high. And groups that are often left out, such as women, are instead fully involved.

To tackle the challenge of improving water productivity, the first step was to understand how water was already being managed and used. This meant doing a baseline study of the entire basin to assess not only water supply and demand, but also upstream and downstream water quality and environmental issues. Researchers used computer models, geographic information systems, and remote sensing technologies to map these features. This baseline information will be crucial in showing the impact of new water management technologies and also in developing effective plans, policies, rights, regulations, monitoring, and water-user groups in the basin.

The Karkheh River Basin has five sub-basins, spans seven provinces, and extends over more than 50,000 square kilometers. The basin is mostly semi-arid but more arid in the south. This means that rainfed crops can only be grown in the upper northern part of the basin. Two-thirds of the population of around 4 million are rural and the per capita income from agriculture is US$230 per year, well below the poverty line.

Surface water provides nearly two-thirds of the water used for irrigation. About 87% of the groundwater extracted is also used for agriculture. The current plan is for the irrigated area below the dam to expand more than three-fold, from 1100 km^2 to 3400 km^2. Since not all of the additional need for irrigation water will be fulfilled by the new dam, a lot less water will have to be used to grow a lot more crops.

To determine ways to do this, researchers looked at current farming practices to pinpoint areas where improvements were needed. They found that yields of the main crops in the upper part of the basin, wheat and barley (76%), and pulses (23%), are low: 920 kg/ha for wheat, 950 kg/ha for barley, and about 500 kg/ha for chickpea. Water productivity is also low, as yields range from 0.3 to 0.5 kg per cubic meter of water. This means that farmers make less than $50 per hectare.

One of the problems is that when autumn rains are late, farmers sow their winter crops in drier soil or delay sowing and the young plants cannot get a good start before winter sets in. Crop stands are poor and plants are not hardy enough to resist the cold and frost. One solution

Poorly managed water conveyance structures and practices in the basin area: the bank of this irrigation ditch has been cut, to convey water across the road to another field – creating problems of excess runoff.

is to use supplemental irrigation so that crops can be planted early and get off to a good start. But this means that farmers need irrigation water, plus some way of getting the water to their fields. Water and irrigation pipes or channels are expensive.

Scientists from Iran's Dryland Agricultural Research Institute, working with farmers on their farms, are testing low-cost ways of supplemental and deficit irrigation, and improved agronomic practices that use water efficiently. This is helping poor farmers improve water productivity in the upper part of the basin.
In the lower basin, below the new dam, water availability is already improving, even though the irrigation and drainage network is not yet finished. A wide range of crops grow in this part of the basin but crop-water productivity and irrigation efficiency are poor. Soil and water quality are at risk. Water losses from canals and irrigation furrows, poor drainage, and salinity, especially in low-lying downstream areas (e.g. Dasht Azadegan), are severe. Salinization is getting worse because there is more irrigation, and also because the river, now restricted by the new dam, no longer floods and washes excess salt out of the soil.

Research findings bear this out. Average cereal yields in the irrigated area (2300 kg/ha) and water productivity (mostly less than 0.5 kg/m^3) are poor. For example, the overall efficiency of the traditional irrigation networks in the Dasht Azadegan area of the lower basin is only 14-23%. Researchers chose Sorkheh and Dasht Azadegan, two large irrigated areas below the dam, for on-farm irrigation experiments to find solutions to these problems. Researchers from the Agricultural Engineering Research Institute in Karaj, the National Salinity Research Center in Yazd, and the provincial Agricultural Research Centers (Dezful and Ahvaz Stations), are working here with farmers to test improved irrigation systems, salt-tolerant crops, and new ways of managing water and salinity.

Participatory research to improve water management in the Karkheh benchmark basin will provide valuable insights into ways to improve the incomes and livelihoods of resource-poor communities in water-scarce regions.

Early outcomes of the water benchmarks project in West Asia and North Africa

The water benchmarks project

Water scarcity in West Asia and North Africa is critical. Yet farmers do not manage water well because they consider that technologies to improve management are not practical. The reasons for this vary and include technical, socioeconomic and policy aspects. But the most important reason why new technologies are not used is because the communities who were supposed to benefit from them did not participate in the development process.

Working with the community in the badia water benchmark project area in Jordan.

To deal with this problem, ICARDA set up a project called Community-Based Optimization of the Management of Scarce Water Resources in Agriculture in West Asia and North Africa in 2004. This is known as the 'water benchmarks' project. The project is supported by the Arab Fund for Economic and Social Development (AFESD), the International Fund for Agricultural Development (IFAD), and the OPEC Fund for International Development. The aim is to find the best ways of helping farmers in WANA improve their production per unit of water used, and so make a better income.

To do this, scientists are working with farmers in three benchmark sites where water is very scarce. They involve communities in research, development, testing, and adapting technologies. The benchmark sites represent the three main agricultural environments in WANA: one for the drier areas (*badia*); the second for rainfed cropping systems; and the third for fully irrigated areas. The water benchmark areas are based on watersheds, determined using remote sensing techniques and geographic information systems (GIS) to integrate biophysical and socioeconomic factors.

Early successes

Early outcomes of the water benchmark project indicate that the community-based approach is spreading to existing and new projects in WANA, and that water policies are changing as a result of successes in the benchmark areas.

In Jordan, the National Center for Agricultural Research and Technology Transfer (NCARTT) is now using the participatory approach in new projects supported by GTZ – for example in the Yarmouk Development Project in the north of the country, and in the northern and southern *badia*. NCARTT has submitted a US$4 million proposal for a national project to disseminate project results to other areas in the *badia* to the Ministry of Environment as part of the Jordan National Action Plan to combat desertification. What is more, the Ministry of Agriculture and NCARTT will make the water benchmark area a permanent research site for the whole *badia* and will build a research and development station in the watershed.

Water harvesting in the Jordanian *badia*

Water harvesting is a way to manage *badia* rangeland resources in a sustainable and integrated way. By harvesting rainwater, farmers can grow shrubs for fodder and drought-tolerant fruit trees, conserve soil, and rehabilitate natural vegetation. A machine (Vallerani) makes construction of water harvesting bunds for micro-catchments much easier. Now, three times as many farmers use water harvesting, compared to before the project. The government of Jordan, keen to expand and scale up the project, has bought a powerful tractor to operate the machine, and will use it for constructing micro-catchments in other parts of the country.

Micro-catchment water harvesting contours in the Jordanian badia.

Terraced furrows systems in Egypt

Conventional furrow irrigation of wheat and other crops in the Nile Delta uses excessive amounts of water. This type of irrigation encourages weeds and so raises labor costs. In addition, applying large amounts of water leaches out nutrients. ICARDA scientists, working with the Agricultural Research Center in Egypt, therefore introduced terraced furrows to communities in the Irrigated benchmark area. Farmers in this area already use a furrow system and were readily persuaded to reduce the amount of water they applied, halve the number of furrows, and grow crops on beds about 1.2 to 1.4 m wide.

This made irrigation more efficient and reduced the costs. Farmers could not over-irrigate because there were fewer furrows to apply water to. When tested in farmers' fields and compared with the conventional system, the terraced furrow system used 30% less water, reduced the cost of pumping and labor for preparing land, irrigating, and weeding by about 35%, while giving the same or higher yields. As the terraced furrows used less water, crop-water productivity (the yield per unit of water used) increased by over 30%, and farmers' net income increased by about 15%. Overall, the net return per unit of water increased by about 20%. Many farmers have already adopted this system or are seeking help to do so. Other development projects in the Delta are taking up the system, as are six other governorates in the Delta and central Egypt where wheat and faba bean are grown.

Early sowing and supplemental irrigation in Morocco

Late first rains are a major limitation in rainfed cropping areas because they delay sowing. In Morocco, and in most of WANA, the first rain may not arrive until a month after the best date for sowing. But, if wheat is sown in October or early November, yields improve by 10-50%. Scientists at the Institut National de la Rechèrche Agronomique (INRA) worked with farmers in Tadla, Morocco, the water benchmark site for rainfed areas, to sow wheat early and apply 50-70 mm of supplemental irrigation. Yields increased by 30% with only 50 mm of supplemental irrigation . This means that, for wheat, supplemental irrigation water productivity was between 1.1 and 1.4 kg/m^3.

Crops in rainfed systems also become stressed in late spring when rains tail off. Supplemental

Wheat crop in Morocco sown early in November with 40 mm of supplemental irrigation (right) as compared with conventional sowing in December.

irrigation at this time greatly increased both yields and water productivity. Existing systems for full summer irrigation can be used for supplemental irrigation instead.

Applying supplemental irrigation early in the spring means that water allocation policies need to change because water is currently allocated to fully irrigated crops. The Office Régionale de Mise en Valeur Agricole de Tadla (ORMVAT), the agency responsible for water allocation in Tadla, is a partner in the rainfed benchmark area and is participating in the analysis to develop a more robust system that will give the highest return on the limited water available for irrigation. Reallocating surface and ground water will be necessary to increase water productivity and improve drought-preparedness.

The 'Water Wand': a simple, cheap probe to detect soil wetting depth

In areas where water is scarce, farmers can grow better crops if they know how much water is in the soil. So, tools that help them find out how far down rain or irrigation water penetrates into the soil, how much soil water is available to plants, and whether there are any soil layers that prevent water filtering down, are helpful.

The Water Wand is a low-cost, easy-to-use probe for estimating soil moisture and compaction.

The Water Wand

Most of the instruments used to measure water in the soil are expensive. They are designed for high-value crops, large farms, and scientific research rather than for farmers in developing countries.

The Brown Moisture Probe, originally developed in Montana, USA, is used by scientists and farmers to determine the depth of soil wetted by precipitation or irrigation. Although this type of probe has been available for over 50 years, it is not commonly used in the dry areas of WANA. So, scientists at ICARDA developed a simple hand-push probe, the Water Wand, based on the Brown Moisture Probe, so that farmers could quickly and easily measure soil moisture.

The probe is a stainless steel rod, 10 mm in diameter and 1.2 m long, with a spherical tip 15 mm in diameter, and a round handle. As the diameter of the tip is 5 mm more than the diameter of the rod, the probe penetrates wet soil but stops when it gets to dry soil. Rocks and gravel may also stop the probe, but can be differentiated from dry soil by a metallic click when the probe is tapped. The probe works on the principle that wet soil is less resistant than dry soil. Resistance to the probe increases rapidly as the soil becomes drier. The probe stops abruptly and begins to flex when it gets to dry soil or a compacted layer.

Scientists tested the Water Wand at ICARDA's Tel Hadya research station in deep heavy clay soil. They wetted four small basins once a week with four wetting regimes. They measured water in the soil profile using neutron scattering (at 150 cm intervals) through tubes installed in the center of each basin.

In 2006, they measured the depth of wetting at several places in each basin twice a week for three months by pressing the Water Wand firmly into the ground until it stopped. To measure how far water had penetrated down into the soil, they placed a hand on the probe at ground level and removed the probe, noting how much of the probe was below the surface.

There was a very strong correlation between the depth of penetration by the Water Wand and the amount of soil water in the four basins. On average, the total amount of soil water (mm) is about 3.2 times the depth of Wand penetration (in cm). The amount of water held by the wet soil depends on soil texture, so this relationship applies only to the heavy clay soil at ICARDA.

Penetration of the Water Wand to 120 cm in the heavy clay soil at Tel Hadya represents about 400 mm of total soil water. The estimated volume of water in this soil at the wilting point is 22%. Subtracting this amount (264 mm) from the total amount (400 mm) leaves 136 mm of soil water available to plants in the 120-cm profile. Further tests on fallow fields and on wheat fields also show strong relationships between the amount of rainfall (or soil wetting) and the depth of penetration by the Water Wand.

Practical use of the probe

By taking measurements with the probe across a field, farmers can estimate the amount of soil water and extent of soil compaction, and can thus manage water more efficiently. If they know how much water is in the soil at the beginning of the planting season they can decide which crop to plant. Rainfall data for previous seasons tells them how much rain they can expect in the growing season. Measuring soil water precisely is time-consuming and expensive. However, the tests with the Water Wand show that the depth of wet soil is another measure of the amount of available soil water for plant use. Each field needs to be probed separately because the variations in soil texture, precipitation, previous crop and tillage practices, and topography all affect soil moisture.

Rainfed cereals and legumes need adequate soil water at crop establishment, and grain-filling and ripening stages. So, the Water Wand is a very useful tool for farmers to estimate soil water routinely during the growing season and schedule supplemental irrigation for these critical periods.

In irrigated fields, the probe can be used a few hours after irrigating to monitor the depth of water, or used before and after to estimate the amount of water that has been applied. Measurements across a field help determine the uniformity of irrigation. Farmers find it hard to determine the cut-off, or cut-back, time of irrigation in long furrows and borders. By probing the lower end of the field while it is being irrigated, the farmer can monitor the depth of wetting and use that information to cut-back, or cut-off, irrigation.

The Water Wand was tested at ICARDA's Tel Hadya station, on uniform, deep, heavy clay soil.

The probe has other uses, for example to quickly check soils in parks, gardens, and tree planting holes for compacted layers with minimal disturbance. If the probe penetrates the soil easily this mean plants develop deep roots, water moves freely down the soil profile (no hardpan), and the soil is easy to till. If the soil is wet and the probe still does not penetrate, this means that the soil is compacted near the surface and prevents water infiltrating and penetration of roots.

Enhancing the productivity of high-magnesium soil and water resources

In 2006, ICARDA researchers continued work to overcome problems caused by soil and water containing high levels of magnesium in Central Asia. The project is funded by the Asian Development Bank.

Excess magnesium in soil leads to a severe degradation of soil structure, and thus lowers water infiltration rates, hydraulic conductivities, and crop growth. More than 30% of the irrigated area in southern Kazakhstan has excess levels of magnesium: exchangeable amounts are generally 25-45%, and in some cases as high as 60%.

Plowing high-magnesium soils typically forms massive clods that impede water flows down furrows and across irrigated fields, and leads to poor water distribution. The problem is compounded when the magnesium content of water is higher than that of calcium.

The Arys-Turkestan canal command area in southern Kazakhstan is a typical example of an area where there is excess magnesium in soil and irrigation water. This has led to a gradual fall in the yields of cotton, with a large impact on farm profitability, since farmers rely heavily on cotton. Winter wheat (*Triticum aestivum*) yields are similarly affected.

Adding enough calcium, often as gypsum or phosphogypsum, can restore the productivity of high-magnesium soils, by counteracting the effects of magnesium. Phosphogypsum is widely available in Kazakhstan and could increase productivity of high-magnesium soils in the Arys-Turkestan canal command area and elsewhere in Central Asia at low cost.

High levels of soil magnesium have a negative impact on hydraulic properties of soil, and plowing forms massive clods that interfere with water flow rates.

Phosphogypsum can be applied in winter before snowfall or after preparing seedbeds, and is often incorporated into the soil by plowing. In low-rainfall years, harrowing the field is recommended to incorporate the phosphogypsum and reduce the risk of it being blown off by the strong winds common in the region. Snowmelt and rainfall in winter make phosphogypsum dissolve more quickly and increase soil calcium levels. These processes can be further accelerated by irrigation. The calcium then replaces magnesium on the soil's cation exchange complex. The replaced magnesium is leached deeper into the soil profile by excess irrigation or rainfall. In such ameliorated soils, there is greater water and air movement, greater root penetration and seedling emergence, and less runoff and erosion. Water-use efficiency is increased and the greater activity of plant roots improves crop growth and yield.

Applying phosphogypsum also improves soil nutrient availability. Studies have shown that 4.5 t/ha of phosphogypsum

Table 1.1. Levels of phosphorus (P_2O_5, kg/ha) in the soil as affected by applying phosphogypsum. Figures in brackets represent the percentage increase from initial levels of P_2O_5.

	Phosphogypsum (4.5 t/ha)		Phosphogypsum (8 t/ha)	
Soil depth (m)	Initial soil	Post-amendment	Initial soil	Post-amendment
0.0-0.2	82	106 (29)	88	141 (62)
0.2-0.4	75	89 (19)	87	112 (29)

increased phosphorus (P_2O_5) levels by 29% and 19% respectively in the top 0.2 m of soil and the 0.2-0.4 m soil layer (Table 1.1). Applying more phosphogypsum (at a rate of 8 t/ha) led to increases in phosphorus of 62% and 29% in the same two soil layers. Applying phosphogypsum also slightly increased soil potassium levels, by 3-5%.

Applying phosphogypsum nearly doubled cotton yields in long-term field studies (Fig. 1.2), partly due to better germination, and better bud and boll formation. Cotton yields increased by 93% in the 4.5 t/ha phosphogypsum treatment and 114% in the 8 t/ha treatment, compared with the control. Adding phosphogypsum increased calcium levels and thus improved the soil's ionic balance and physical properties.

The appropriate rate of phosphogypsum addition to a high-magnesium soil is crucial and depends on the initial soil magnesium level. Applying phosphogypsum at below the actual requirement only partly ameliorates the soil, while applying more than is needed is costly for farmers.

The effects of phosphogypsum applied to a high-magnesium soil may last for several years. Studies by ICARDA researchers have shown that where high-magnesium water is used to irrigate ameliorated soils, the magnesium levels tend to increase and calcium levels gradually decrease 4-5 years after applying phosphogypsum. Under these conditions, booster applications of phosphogypsum are needed to maintain desirable magnesium levels and good crop yields.

Excellent growth of cotton on a high-magnesium soil, after applying phosphogypsum.

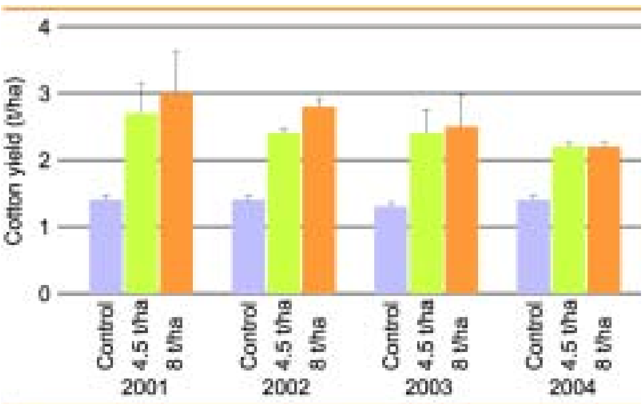


Fig. 1.2. Cotton yields with phosphogypsum application rates of 0 (control), 4.5 and 8 t/ha on a high-magnesium soil in southern Kazakhstan.

The beneficial effects of phosphogypsum on cotton productivity on high-magnesium soils have been clearly demonstrated in farmers' fields. This is a practical economic recommendation for Central Asia that is also applicable to other crops such as wheat.

Watershed modeling to help decision-making on water use

Over many centuries and in many places in Tunisia, a wide range of small- to medium-sized water-gathering structures have been introduced to make the land productive. Water harvesting is especially important in the arid southeast, where the rainfall of 150-230 mm/year is too low for crop production.

There are many water users, from rainfed farmers in upstream areas and foothills, pastoralists that graze the downstream plains with camels, goats, and sheep, to groundwater users and providers that serve towns, tourism, and industries. The many users and changing socioeconomic conditions has led to demand for a management scheme at the watershed level to allow fair and productive partitioning of water between users.

Traditionally, water-harvesting was confined to *wadi*-courses in the mountain zones, where local communities built small stone dams to capture water and sediments. The resulting fertile terraces, known as *jessour*, were planted with fruit trees and often with small rows of field crops. During the last 50 years there has been a gradual extension of cultivated fields, especially of olive trees, along the mountain foothills, and earthen dikes and diversions on the gently sloping lands distribute the water among these so-called *tabias*.

In the 1990s, the Ministry of Agriculture invested in the system

***Jessour** water-harvesting system in Oum Zessar watershed, Tunisia: olive trees prosper on the runoff water and sediments captured by the stone dike.*

by developing check dams in the main *wadis* in the mid and downstream areas. These check dams slow runoff water, improve groundwater recharge, and allow diversion of water to newly established *tabias*. Migration of the younger generation to towns and cities is reducing the labor available for maintenance of traditional water-harvesting systems in upstream areas, creating the potential for flooding disasters during large rainfall events.

To better understand the effects of the diverse natural and man-made landforms on the water flows in these arid environments, researchers from Tunisia, ICARDA, and Purdue University (USA), modified the GIS-based watershed model SWAT. Research focused on Wadi Oum Zessar (Fig. 1.3), a 340-km^2 watershed in southern Tunisia, which stretches from the Matmata Mountains across the Jeffara Plain before it spreads its flood waters along the large salty plains (*sabkhat*) downstream and disappears into the Mediterranean Sea.

The watershed model was adjusted for typical Mediterranean cropping conditions and special subroutines were developed to simulate the capture and use of runoff by different water-harvesting systems at the sub-watershed level. Basic data layers were constructed using available maps, remote sensing images, and fieldwork. Thus, a database containing parameters for the model was set up and evaluated using historical runoff records. The modeling improved understanding of the system and the water distribution between different watershed uses.

Typically for arid environments, the great variation in rainfall in space and time made it difficult to accurately simulate all recorded runoff events. However, the model captured the behavior of the system and simulated the overall water balance components well.

Evapotranspiration was the largest water user in the upstream and midstream areas, using 80% of the average annual rainfall of 184 mm for the 12-year evaluation period. Around 13% of the rainfall percolated from the predominantly shallow soils, 5% recharged groundwater through transmission losses from the *wadi* beds, and 4% flowed to the downstream plains. Researchers are currently modeling the effect of land use changes on water use and productivity in the watershed, using the results of the established baseline scenario.

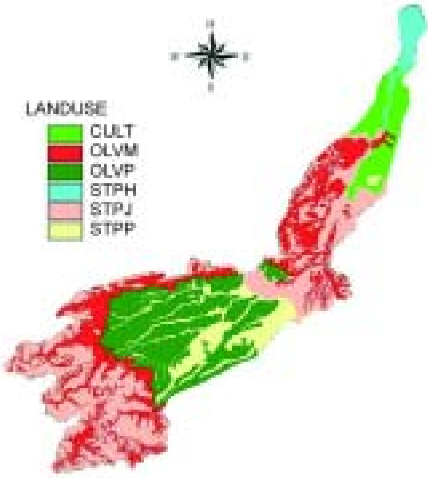


Fig. 1.3. Land use map of Oum Zessar watershed with olive trees on the jessour terraces (OLVM) and tabias (OLVP) in the upstream and midstream areas, and rainfed cereals (CULT) and sparsely covered rangelands (STPH, STPJ, STPP) occupying the remainder of the watershed.

Integrating water harvesting and soil conservation to combat desertification

In 2000 the United Nations Convention to Combat Desertification (UNCCD) launched a Sub-Regional Action Program (SRAP) to combat desertification and drought in West Asia. This program involves several national and international partners, including ICARDA. As part of the program, pilot projects were launched in Jordan and Lebanon.

Pilot project, Jordan

ICARDA has established a pilot project in cooperation with the National Center for Agricultural Research and Technology Transfer (NCARTT) at Fa'a, Mufraq province, in the north of Jordan. The 15-km^2 watershed, inhabited by 348

Low-cost check structures have proved effective in stopping runoff water and retaining the soil it carries.

This nursery provides seedlings of medicinal and other valuable plants introduced by the project for the farmers to grow using harvested rainwater.

households, is steeply sloping, gullied, and has shallow, easily eroded soils. Runoff in the upper catchment is the main cause of desertification, although only 160 mm of rain falls per year.

Cultivation of barley on slopes and the edges of gullies accelerates erosion. Soils are rapidly losing fertility. Livestock production – a mainstay of the local economy – has declined because the rangeland no longer provides enough grazing, and farmers cannot afford to buy feed concentrates.

Communities have tested several methods of preventing erosion. For example, planting cactus in rills and gullies to prevent them from expanding; and building check structures and bunds to stop and divert runoff. They also built parallel stone ridges, 5-10 m apart, to stop runoff water and soil loss. These contour ridges collect runoff from immediately upstream or uphill and channel the water to 1000 fodder shrubs. The combination of well-designed ridges and drought-tolerant shrubs helps communities rehabilitate rangeland and improve fodder supplies.

Another method was strip cropping, i.e. alternating strips of crops and fallow, with the latter acting as miniature rainwater catchments. The ratio of cropped to fallow area ranges from 1:1 to 1:3, depending on the slope, soil type, and rainfall. This system doubles or triples the amount of rainwater harvested, giving much higher and more stable yields.

The project also introduced techniques for building water reservoirs. Small ponds are easy to build, even on slopes. Farmers simply choose a suitable depression and block off the lower end with a masonary wall. On a slightly larger scale, a low-cost earthen dam can meet most of a community's needs for domestic water, supplemental irrigation, and livestock. The size of the reservoir can be matched to the amount of runoff and the labor and material available for construction. In the pilot project, the community built a pond and a mini dam, which together store about 6000 m^3 of water. The cost was shared between the pilot project (60%), and the government and the community (40%). Villagers also used the water harvested to grow new crops brought in by the project, such as medicinal plants, which can be grown in home gardens and are quite profitable.

Pilot project, Lebanon

Two pilot sites in the Lebanese mountains, Yemouneh and Deir El-Ahmar, were established in cooperation with the Ministry of Agriculture. These areas are often affected by flash floods, resulting in sheet and gully erosion. Erosion reduces the soil's capacity to store water, so it retains very little moisture. Yemouneh is 1360 m above sea level, with significant snowfall and an average precipitation of 650 mm per year. The community of 3500 people cultivates 541 hectares of the 2950-hectare catchment. The other pilot site, Deir El-Ahmar (population 15,000), is mainly community-managed rangeland and forest.

Twelve farmers built stone and earth structures to harvest water in their fields, which was then used to irrigate fruit trees. These structures also conserve soil. Similar small structures on steep slopes support shrubs and forest trees.

The construction of ridges and dikes was timed so that seedlings could be planted in

Small water reservoirs were built at project sites in Lebanon, to collect and store runoff water for use by livestock.

the right season. Project staff advised farmers on how to water the plants until they were established. The farmers planted fruit trees, including some seedlings of drought-tolerant trees, such as almond.

Water reservoirs were constructed at both Yemouneh and Deir El-Ahmar. The reservoir at Yemouneh, ointly managed by the community and the municipality, harvests and stores 5500 m^3 of water, which is used to water orchards and vegetables. The reservoir in Deir El-Ahmar holds 6000 m^3. The efficiency of the reservoir averages 75%, meaning that 4500 m^3 of water is available for irrigation. In winter the reservoir stores surplus water which is then used for irrigation in summer.

Lessons learned from the pilot projects

Although most members of the communities now acknowledge the fact that land degradation is threatening their livelihoods, their demands for improvements are directed towards short-term economic gains, and improving their livelihoods.

The project found that in the pilot site areas, public and communal land was threatened more by degradation than were private lands. The open access policy to rangeland causes severe degradation.

The Lebanese pilot study in particular showed that land degradation cannot simply be explained by an increase in population pressure. Land degradation on slopes happens when the land is neglected, or not farmed for want of labor. As there is considerable out-migration from the pilot area because of unemployment, only major changes would attract people to live in rural areas and work in agriculture.

The project concluded that appropriate rainwater harvesting, together with soil conservation, can improve productivity and reduce soil erosion.

Simple water harvesting techniques provide water for irrigating fruit trees.

Rainwater harvesting is a useful way of improving the vegetation cover to combat desertification in environments similar to those in the pilot sites. A preliminary assessment shows that low-cost, simple technologies, such as those tested in the pilot sites, are easy to adopt and replicate. These serve both productivity and conservation, and thus are sustainable.

Harvesting water in micro-catchments to combat desertification

More than half of the land area in the eastern Mediterranean is rangeland and most is degraded to some extent. To rehabilitate rangeland and provide more feed for animals by planting fodder shrubs, ICARDA scientists are working with communities to test techniques for harvesting runoff and directing it to individual plants. This is known as micro-catchment water harvesting. The three-year project, financed by the Swiss Development Cooperation (SDC), began in 2004 at three pilot sites, two in Syria and one in Jordan (Table 1.2).

Researchers and farmers worked together to test the Vallerani plowing implement, pulled by a tractor, which constructs contour ridges and bunds mechanically and which has already proved successful in large-scale water-harvesting projects in Central Africa. The Vallerani implement makes an angled furrow and piles up the excavated soil on the lower (downhill) side. This soil forms a ridge that stops or slows down runoff water. The implement can be used either to create continuous furrows or intermittent ones. The effectiveness of the Vallerani implement was compared with a similar Pakistani plowing implement that also creates continuous furrows, and with manual construction of intermittent semi-circular micro-catchments

Researchers and farmers then planted shrubs at the lowest part of each micro-catchment, where the run-off water collected. Three shrub species were planted: *Atriplex halimus, Atriplex leucoclada*, and *Salsola vermiculata*. Researchers gathered and analyzed data on rainfall, vegetation cover, and the survival and growth rate of the shrubs. They also measured soil water content (using 108 access tubes), and soil erosion (using 21 runoff collecting tanks, erosion measurement pins, Gerlach troughs, erosion bridges, and weirs).

Three main lessons have been learned from the pilot projects. First, water harvesting can help to establish shrubs where there is very little rainfall and the likelihood of success would otherwise be very slim. Second, water harvesting also improves the growth rate of shrubs significantly in higher rainfall sites (150-220 mm) and, third, mechanizing construction improves the efficiency of water harvesting.

Table 1.2. Characteristics of pilot sites in Syria and Jordan and details of micro-catchment water harvesting experiments conducted at each.

Description	Qaryatein, Syria	Sheikh Hilal, Syria	Muhareb, Jordan
Annual rainfall (mm)	120	220	152
Watershed area (ha)	300	50	60
Size of experimental site (ha)	100	12	13
No. of participating farmers	17	12	5
Techniques for making micro-catchments tested†	Vi, Vc, P, Manual	Vi, Vc, Manual	Vi, Vc
Spacing of ridges (m)	6 and 12	6 and 12	4 and 8
Total length of ridges created (km)	85	4	5
No. of shrubs planted	10,000	500	1200

†Vi = Vallerani implement used to make intermittent furrows (this creates small basins); Vc = Vallerani implement used to make continuous (unbroken) furrows; P = Pakistani implement used to make continuous furrows


In Syria, micro-catchments developed using the Vallerani plow collect rainwater (left) and support good production of shrubs (right).

In the low-rainfall site of Qaryatein, Syria (120 km east of Damascus), water harvesting added considerable amounts of water to the soil. Runoff from slope lengths of 6 m and 12 m (the distance between ridges, Table 1.2) was 5 and 8 liters per square meter respectively. After 24 hours of rainfall there was far more soil moisture where shrubs were planted than in the catchment area (Fig. 1.4). This means that the micro-catchments were successful in capturing runoff and directing the water to the plants where it was needed. The survival rate for shrubs in the first year of the project was very good: 77-99% for *Atriplex halimus*. In the second year (2005/06) survival rates dropped, as the site received only 40 mm of rain – just one-third of the average. The survival rate was highest for shrubs grown in semi-circles and lowest for the Pakistani plow.

In Sheikh Hilal, Syria (50 km north-east of Salamieh), water harvesting improved the growth rate of shrubs significantly. The soil-moisture content for the areas where water was harvested rose on an average by 16% in February, 14% in March, and 16% in April compared to areas where water was not harvested.

The survival rate of shrubs was excellent (97% for A. *halimus*, 96% for *S. vermiculata*, and 93% for *A. leucoclada*) and did not differ much between the various water harvesting techniques. When water harvesting raised the soil-moisture content by less than 10%, there was no difference in the performance of shrubs in the areas where water was harvested and those where it was not. The survival rate of shrubs in Sheikh Hilal was higher than in Qaryatein probably because the rainfall was higher.

In Muhareb, Jordan (65 km southeast of Amman), the soil-moisture content was highest in February and lowest in October following a long rainless period. In order of effectiveness, the best techniques for directing runoff to plants, in terms of soil-moisture content, were the Vallerani intermittent micro-catchment (8 m spacing between ridges), followed by the Vallerani continuous micro-catchment (8 m spacing) and the Vallerani intermittent micro-catchment (4 m spacing). Soil erosion from rain splash was least in the unplanted control area (13.75 t/ha), more in the test areas (20.75 t/ha), and even higher on ridges (24 t/ha) and in barley fields (30 t/ha).

The harvesting of runoff water per unit area was most efficient in the 4-m spacing micro-catchments. These also trapped the most soil per meter of slope. The survival rate of shrubs ranged from 78% to 97% and there was not much difference between

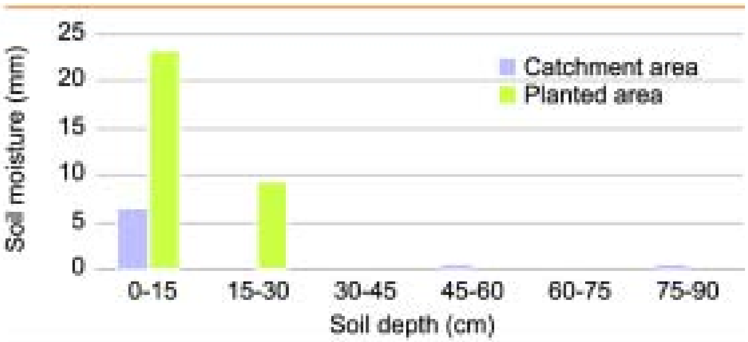


Fig. 1.4. Change in soil moisture 24 hours after rainfall in Qaryatein, Syria. In the parts of the water-harvesting areas where the shrubs were planted, soil moisture levels had increased far more than in the catchment area.


Scientist measures shrub growth and productivity (left); improved feed supplies directly benefit livestock (right).

treatments. Plants produced relatively more biomass in water-harvesting treatments as compared to the control, but again there was not much difference between the treatments.

This means that in higher annual rainfall areas (150-220 mm), water harvesting can improve shrub growth rates significantly. The tractor with the Vallerani implement created micro-catchments on 1.2 hectares per hour, and used 46.3 liters of fuel per hectare. A preliminary benefit-cost analysis showed an average net return of around US$30 per hectare. This means that using the Vallerani equipment to mechanize construction improves the efficiency of water harvesting. However, the performance of the equipment in shallow soils needs to be investigated further. Researchers will study this in 2007.

Irrigation methods to improve water productivity of cotton in Syria

Water deficits in Syria are already severe, and getting worse. National water consumption is estimated at 14.7 billion m^3/yr. Estimated available water resources are 12.94 billion m^3/yr, leaving an annual deficit of 1.73 billion m^3. Water balance in most basins is negative, except for coastal areas and the Euphrates basin. For example, at Tel Hadya in northern Syria, the water table has fallen by 35 meters in 20 years.

Springs in several parts of the country have dried up. Rapid expansion of irrigated land (supported mainly by groundwater extraction) and inadequacies in water delivery and use are the major causes.

Agriculture accounts for 89% of the country's total water consumption. The largest consumer is cotton, which uses 3.7 billion m^3/yr, or 30% of agricultural water. Cotton is the most important cash crop in Syria. Nearly one-fifth of the economically active population derives all or part of its income from cotton production and processing. However, over 95% of cotton in the country is grown using inefficient (even wasteful) methods of water management, such as low-efficiency surface irrigation and excessive water applications. ICARDA is working with Syrian partner institutions to develop and promote technologies to improve water-use efficiency in cotton irrigation.

Complementing national efforts

In 2001, the Syrian government adopted a modernization plan aimed at sustainable water resources and irrigation development. Old irrigation projects are being rehabilitated and modernized. Farmers are being encouraged to adopt modern techniques like drip irrigation to improve on-farm irrigation efficiency, by providing tax-free low-interest loans to cover the initial capital costs. However, adoption of these technologies is growing only slowly. To complement national efforts to promote modern systems, ICARDA researchers focused on ways to improve existing, inefficient surface-irrigation systems. Given the widespread use of such systems, the returns to such research are potentially huge.

Average seasonal irrigation for cotton in Syria is about 15,000 m^3/ha, and much higher application rates are not uncommon. In fact, seasonal water requirements for the crop are only 7000-8000 m^3/ha. Because of over-irrigation, cotton water productivity in areas using traditional surface irrigation is 0.07-0.09 kg of lint cotton per cubic meter of applied water. Compare this with water productivity in surface-irrigated fields elsewhere: 0.13-0.16 kg/m^3 in Turkey, 0.23-0.39 kg/m^3 in USA and Argentina. The low water productivity of cotton in Syria is a major factor in the country's water deficit, although a number of low-cost, practical solutions are available.

Improved irrigation management methods are available that can significantly increase water productivity in cotton.

Field experiments at ICARDA and Syrian research stations have clearly demonstrated the potential for producing more cotton per unit of water – higher yields with the same amount of water, or the same yield with less water – by sound irrigation and agronomic practices. One Syrian study showed that water productivity of seed cotton can increase from 0.2 kg/m^3 under flood irrigation to about 0.4 kg/m^3 under furrow irrigation, with irrigation efficiency increasing from 40% to about 65%. Another study in hot, dry central Syria showed that drip irrigation could reduce irrigation requirements by 35 to 55%; and that drip irrigation combined with fertigation gave nearly 50% higher yields than conventional surface irrigation.

A two-year cotton-wheat rotation experiment at ICARDA's principal research farm at Tel Hadya showed that water requirements of cotton could be fully met with 7900 m^3 of water using drip irrigation, and an improved irrigation schedule based on soil water depletion. This corresponds to a water productivity of 0.51 kg/m^3 of seed cotton (or 0.18 kg/m^3 for lint) – double the national average. The experiment produced an average yield of 4008 kg/ha of seed cotton, which is the same as the national average, but used less than half the water typically used by farmers in Syria. In other words, *double* the crop per drop!

Farmer innovation in Syria: improved irrigation techniques and locally fabricated delivery systems.

Methods to improve water productivity

One important way to enhance water productivity, particularly in dry areas, is by improving irrigation scheduling, based on regular monitoring of soil moisture conditions during the season. Most farmers in Syria lack the knowledge or the tools to monitor soil water depletion for proper scheduling. Traditional methods, such as 'soil feel' and 'soil probe' are fairly effective, but users must have sufficient experience. A practical approach would involve considerable effort by local agricultural extension staff to compute and publicize daily or weekly crop water requirements for the main crops in the area.

There are many examples of effective, low-cost methods to improve irrigation efficiency. These include use of furrow irrigation, lined canals to reduce seepage, collapsible or solid conduits for head ditch delivery, siphon tubes and gated pipes for better furrow flow control and flexibility, land grading for enhanced flow and distribution, and surge flow and cutback methods for improved furrow efficiency. Experience shows that simple improvements can produce significant benefits.

Two other management practices are important. One is skip furrow (or alternate furrow) irrigation, where the farmer irrigates only every alternate furrow. With half the furrows skipped, excess irrigation is automatically cut back. This technology requires no capital or time investment and can be easily implemented. Further testing in Syria is needed to quantify the large potential water savings. The other practice is deficit irrigation, which could help farmers manage limited water supplies and mitigate the effects of drought. At present, most farmers irrigate their crops with a view to maximize yield per unit of land. This strategy – maximum irrigation for maximum production – is both unwise and unsustainable in basins where water is being withdrawn faster than it is being replenished. But more sustainable alternatives such as deficit irrigation are perceived to be less profitable. Government incentives and policy support will be needed to encourage adoption.

The Syrian government's irrigation modernization plan is expected to produce national water savings of 2.9 to 4.1 billion m^3/year. This would more than wipe out the current national deficit of 1.73 billion m^3, and could support expansion of irrigated land and/or meet other demands such as for drinking and industry. Part of these savings will come from better irrigation efficiency. Water productivity is expected to double, through adoption of drip irrigation, improving the existing surface irrigation methods, encouraging sound on-farm water management, and strengthening extension support.

As water supplies become even more scarce, efficient irrigation is critical – and so are targeted policies to encourage resource-poor farmers to adopt new irrigation and water management technologies.

Mega-Project 2

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

Introduction

The Integrated Gene Management Mega-Project (Mega-Project 2) seeks to contribute to the improvement of livelihoods of resource-poor farmers through the conservation, improvement, and sustainable use of agrobiodiversity and the 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 is fully involved in the CGIAR Generation Challenge Program and the HarvestPlus initiative.

The ICARDA-CIMMYT Wheat Improvement Program (ICWIP) in CWANA has established strategies and guidelines on wheat networking with the NARS, joint fundraising, and priority setting. ICWIP made significant progress in 2006. The Global Rust Initiative (GRI), formed by CIMMYT and ICARDA in response to the threat of the new wheat stem rust (Ug99) emerging from eastern Africa, also made good progress.

Mega-Project 2 links components of basic and strategic research with appropriate field evaluation across a diverse range of environments. The research portfolio includes the following activities: stress tolerant (drought and heat) cereals (barley and wheat) and cool-season food and feed legumes for crop diversification; enhanced wheat germplasm for water-use efficiency (in collaboration with CIMMYT); biofortified barley and lentils for improved nutrition and health (within the HarvestPlus Challenge Program); new traits through gene discovery for crop diversity (with the Generation Challenge Program); improved methodologies and tools for genetic improvement (such as participatory plant breeding, international crop information system (ICIS), doubled haploids, etc.); integrated pest management (IPM) options for the control of diseases and insect pests; and capacity building in NARS.

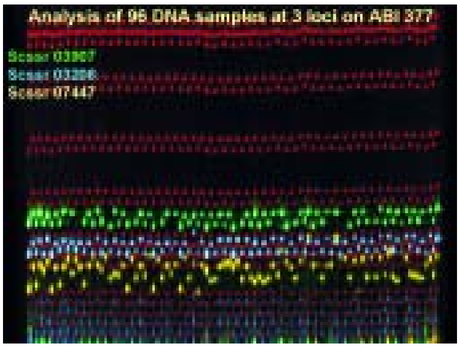
Exploring genetic variability in barley for drought tolerance

A major aim of ICARDA's barley breeding program is to produce high-yielding varieties which are adapted to dryland conditions and resistant to drought. The wild progenitors, wild relatives, and landraces of barley are a rich reservoir of genes adapted to harsh environments. For example, landraces from very dry countries are likely to carry genes for drought tolerance. So the program is now mapping the genetic diversity in ICARDA's collection of Syrian and Jordanian barley landraces to find promising material.

Scientists chose landraces from five barley-growing regions in Syria and Jordan to study micro-satellite diversity. They used 48 simple sequence repeat (SSR) markers on seven chromosomes. They found 368 alleles, and an average of 7.3 alleles per locus. This means that there is a high level of polymorphism in the collection as a whole. But polymorphism differed between the seven chromosomes. For example, the mean number of alleles located on chromosome 1H was 3.8, whereas the mean number on chromosome 6H was 12.3. Some of the alleles only occurred in one country.

The most frequent alleles in the Jordanian landraces were quite different from the most frequent in the Syrian landraces (Table 2.1). A clear example of this is allele 14 on the locus Bmag353, which is common in Jordan (40%) but rare in Syria (3.3%).

The frequency of alleles was used to determine the genetic distance between landraces in the five regions. The resulting dendrogram shows that the barley landraces in each of the five regions are genetically distinct and that genetic diversity in Syrian landraces is much higher than in Jordanian landraces (Fig. 2.1). The genetic differences in these barley landraces will be studied further in the search for novel genes that confer resistance to drought. The drought-resistance genes found will be used to improve barley germplasm for dryland barley production.



Use of SSR markers is providing new insights on genetic variability in barley for drought tolerance.

Table 2.1. Frequency of alleles in Syrian and Jordanian barley landraces.

Allele on locus Bmag353	Percent frequency of allele	
	Syria	Jordan
Bmag 353-1	7.10	18.30
Bmag 353-2	0	1.60
Bmag 353-3	4.40	0
Bmag 353-4	11	1.60
Bmag 353-5	18.70	6.60
Bmag 353-6	13.80	5
Bmag 353-7	2.70	1.60
Bmag 353-8	2.70	1.60
Bmag 353-9	14.30	1.60
Bmag 353-10	2.20	5
Bmag 353-11	12.15	0
Bmag 353-12	7.10	16.60
Bmag 353-13	5.50	18.30
Bmag 353-14	3.30	40
Bmag 353-15	1.60	0

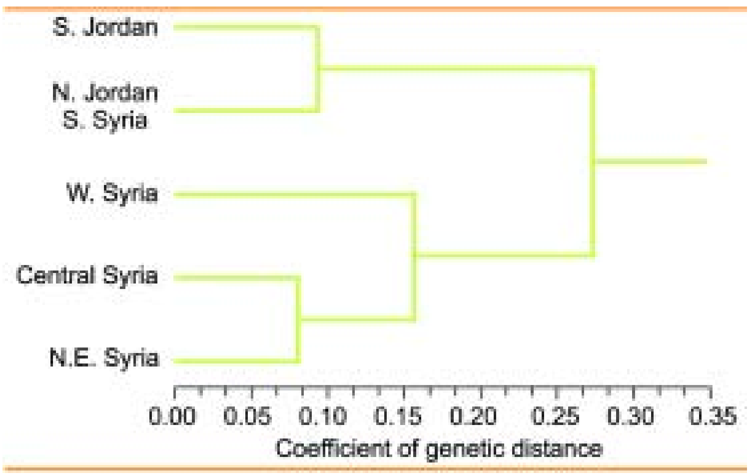


Fig. 2.1. Dendrogram showing the genetic distance between barley landraces from five regions in Syria and Jordan (South Jordan, North Jordan/South Syria, West Syria, Central Syria and Northeast Syria).

Varieties discarded in official testing perform surprisingly well in participatory plant breeding trials

In many developing countries farmers often plant local landraces rather than new varieties that have been formally released. This is particularly the case in marginal environments. These less productive areas can be quite diverse and need a range of varieties for specific environmental niches. But most new varieties are bred for widespread use over major, fairly uniform farming regions. Involving farmers in testing new varieties that had previously been rejected in official testing for release showed that some of these varieties performed unexpectedly well on farms in marginal areas.

In Syria, the system of releasing new varieties is similar to that in many other countries. New varieties are tested in so-called 'on-farm trials', though up to one-fifth of these often take place on research stations. Even when trials are carried out in farmers' fields, it is the researchers who determine the cultivation methods – often different from those normally used by farmers – and involvement of farmers is limited to making land available for the trials.

New varieties are tested in on-farm trials for three years, then a report on agronomic performance, resistance to pests and diseases, and the quality of the crop is submitted to the variety release committee in the Ministry of Agriculture. If the new variety is to be released, it is given a name and becomes legal. Only then may farmers test the variety and decide whether or not it is better than those they already grow. The whole selection and release process can take up to 15 years and is a significant investment of time and resources. But, sadly, the new varieties released very often have not been suitable for farmers in marginal environments; so most are rejected immediately after release and others after farmers have tried them for just one year.

Three new barley varieties, 'Tadmor' and 'Zanbaka' (two pure lines selected from the black-seeded 'Arabi Aswad' Syrian landrace) and 'Harmal' (a white-seeded pure line from the cross Union/CI03576//Coho), were tested in 'on-farm trials' between 1983 and 1993. Subsequently, these three varieties were tested as part of ICARDA's participatory plant breeding (PPB) program. PPB trials differ from on-farm trials in three ways. First, the trials all take place in farmers' fields. Second, normal farming practices for the area are used. Lastly, farmers participate in evaluating the lines and decide which to select. As in the on-farm trials, two local landraces 'Arabi Abiad' (white-seeded) and 'Arabi Aswad' (black-seeded) were grown as checks.

In the on-farm trials (Fig. 2.2) the yield of 'Harmal' was 7.5% higher than the check 'Arabi Abiad' in 1983, as measured in six locations, but nearly 8% less in 1985, as measured in five locations. Overall, across the 11 locations in the two years, 'Harmal' gave slightly inferior results to 'Arabi Abiad' (0.2% lower) and was withdrawn without being submitted for release.

But, in 2001, 'Harmal' was introduced as a check in PPB trials. In 34 trials over five years the grain yield of 'Harmal' was consistently higher than 'Arabi Abiad' and, when all characteristics were taken into account, it was nearly 12% better.

The discrepancy in the results may be because 'Harmal' is specifically adapted to the Salamieh area, Hama province, where the PPB trials took place. Here, between 2004 and 2006, the area planted to 'Harmal' grew from 40 to over 1,000 hectares, indicating its popularity with farmers. 'Harmal' also performed well in PPB trials in Jordan between 2001 and 2003, perhaps for the same reason.

Similar discrepancies between the results of on-farm and PPB trials were observed in the case of 'Tadmor' and' Zanbaka'. In 26 on-farm trials over four years, the yields of 'Tadmor' and

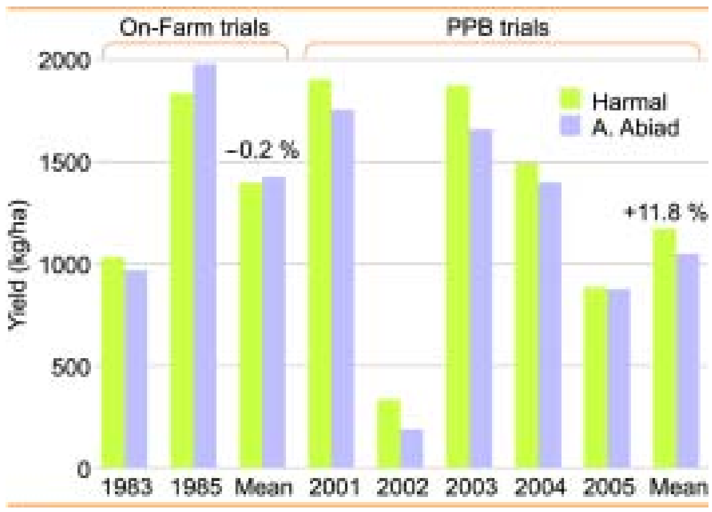


Fig. 2.2. Grain yield of 'Harmal' and 'Arabi Abiad' in on-farm trials in 1983 and 1985 and in participatory plant breeding (PPB) trials between 2001 and 2005. The grain yield of 'Harmal' was higher in PPB trials.

'Zanbaka' were only 3.6% and 1.5% higher than the check, 'Arabi Aswad', and so they too were withdrawn without being submitted for release. However, when tested in PPB trials, the yields of 'Tadmor' and 'Zanbaka' in 55 trials over three years averaged nearly 20% and 17% respectively more than those of 'Arabi Aswad'.

Farmers in the Raqqa and Hassakeh provinces of Syria, and in Gezira, Iraq, have a strong preference for black-seeded varieties of barley, such as 'Tadmor' and 'Zanbaka'. Both varieties have been adopted to various degrees in these areas. Farmers are also using 'Zanbaka' in the driest parts of Aleppo province.

It is not yet clear why the results from the on-farm trials and the PPB trials are different. But the discrepancies may be due to a combination of factors, such as location (on-farm trials are usually conducted on the best land in the area), trial management (rotation and agronomic practices are optimized in on-farm trials), and statistical methods (as those used to analyze on-farm trials do not take spatial variability into account).

Developing marker-assisted selection for resistance to *Barley yellow dwarf virus*

In economic terms, *Barley yellow dwarf virus* (BYDV) is the most serious viral disease of cereals worldwide. Planting resistant or tolerant cultivars is the most effective way to limit losses from this disease. There are only a few genes that confer resistance in barley, such as *Yd2* on chromosome 3H. In some cultivars, several quantitative trait loci (QTLs) for tolerance to BYDV have been mapped in addition to *Yd2*. The *Yd3* gene on chromosome 6H may be the second most important gene for resistance to BYDV.

Researchers from ICARDA's Virology and Biotechnology Laboratories therefore investigated whether polymerase chain reaction (PCR) could be used to detect these genes – and which QTL markers were best. The aim was to allow the marker-assisted breeding of resistant barley lines.

The study was conducted during three growing seasons from 2002 to 2006. In the first season, 88 Ethiopian barley accessions from the Vavilov Institute and ICARDA genebanks were planted in the field, and all plants were inoculated with the BYDV serotype PAV using the virus-carrying aphid *Rhopalosiphum padi*. Researchers assessed the plants' BYDV concentration 30 days later using tissue-blot immunoassays.

A total of 107 plants from 19 accessions with mild symptoms and low virus concentrations were harvested individually and re-planted in greenhouses for further analysis. Five seedlings from each plant were tested for the *Yd2* gene by PCR using the YLP-CAPS marker. Researchers found 38 plants from 14 accessions that lacked *Yd2*.

The 38 plants that lacked *Yd2*, five resistant parental lines with *Yd2*, and two susceptible parental lines were then tested with a set of microsatellite markers closely linked to *Yd3* on chromosome 6H. Some of the parental lines harbored *Yd2* and/or *Yd3*. The marker Bmac0018 was found to amplify a resistant allele in all 38 resistant plants (Fig. 2.3). *Yd2* and *Yd3* seemed to reduce the chance of plants being infected by the viral isolate used.

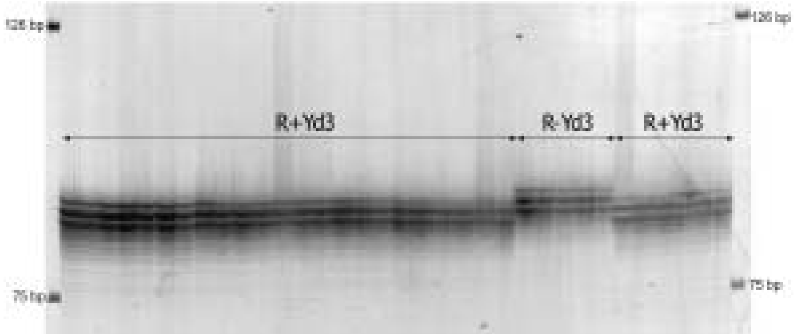


Fig. 2.3. Resistance screening for* Barley yellow dwarf virus*, based on the* Yd3 *gene on chromosome 6H, using marker-assisted selection. R+Yd3 represents resistant lines which have the* Yd3 *gene. R-Yd3 represents susceptible lines which do not have the* Yd3 *gene.

In conclusion, the YLP-CAPS and Bmac0018 markers enable quick detection of the *Yd2* and/or *Yd3* genes in a genotype, respectively. The PCR screening method is rapid and efficient, and if optimized could be used to screen thousands of barley lines for BYDV resistance at the seedling stage, based on *Yd2* and *Yd3*. PCR could also be used to identify resistance based on new genes, other than *Yd2* and *Yd3*, which will have great benefit for increased resistance in future varieties.

Malting barley for poverty reduction

Malting barley accounts for 20% of the world's barley production and is in great demand for making malt-based industrial products, mainly beverages and food products. Most malt is used for alcoholic drinks, such as beer and whisky, but malt and malt extracts are increasingly important in the baking and baby food industries. In Iran, for example, barley malt is mainly used to produce high-energy infant food and non-alcoholic beer. Global demand for beer is growing rapidly, particularly in many developing countries, making malting barley an important cash crop. This is important for poorer farmers in areas where barley may be the only possible crop, such as the highlands of Ethiopia, Eritrea, and the Andean region.

Early generations of new malting barley varieties in Mexico.

An ICARDA survey in Ethiopia's Arsi Region showed that malting barley is a multi-purpose crop, grown as food for household consumption and for sale. The thin hull makes it easier to dehull than traditional varieties, and it yields more flour. Thus, it has high value for brewing malt and can also be used for traditional foods.

ICARDA has a global mandate to improve barley in developing countries, so one of the objectives of its Barley Improvement Program is to develop malting varieties that meet the specific quality standards of breweries and also the needs of poor farmers. The program has therefore established a collection of most of the well-known malting varieties available worldwide and collaborates with advanced research institutions and private companies. It has developed low-cost screening techniques to identify barley lines with good malting qualities in collaboration with the Al-Chark Brewery Company in Syria.

In 2000, ICARDA's Latin America program worked with the agricultural research branch of the brewer, Anheuser Busch Co., to develop new barley varieties with improved malting quality and multiple disease resistance, particularly to *Fusarium* head blight. The increased focus on malting quality has enhanced collaboration with countries that primarily use barley for malt, including Brazil, Uruguay, Argentina, and Mexico.

The barley line 'V-Morales' is a product of this successful collaboration. It has better malting quality and gave higher yields than local varieties in several on-farm trials in Mexico, Brazil, and Peru. It also has high resistance to the most important diseases, and will be registered as a Mexican cultivar in 2007.

In the coming seasons, newer varieties will be identified and provided to growers worldwide. Varieties with better malting quality are expected to improve incomes of some of the poorer farmers in developing countries.

Deeper root penetration to improve drought tolerance in durum wheat

In durum wheat (*Triticum turgidum* var. *durum*), genetically improving drought resistance is the most important way to increase yield in the Mediterranean region. Extensive and deep roots are important for extracting residual moisture from various soil layers. Compaction in the subsoil can limit deeper root growth to subsoil layers. This reduces water and nutrient uptake, aboveground biomass, and grain yield. One of ICARDA's breeding objectives, therefore, is to improve root penetration to allow stable durum production in hardpan soils and under drought conditions.

A simple technique was adopted from screenings at Hokkaido University, Japan. This involves using a mixture of 40% paraffin and 60% petroleum jelly (Vaseline) as a substitute for a hard soil layer. The method has been used by other researchers to screen the root penetration ability of rice, cotton, and wheat. Wheat genotypes with a high root penetration ability can develop more roots in deep soil under hard soil conditions than other genotypes.

The study looked at several landraces, improved cultivars, and one line of *Triticum dicoccoides*. The best landraces were found to be 'Haurani', 'Jennah Khetifa', and 'Camadi Abu' (Fig. 2.4). The best cultivars were 'Korifla' and 'Omrabi 5'. *Triticum dicoccoides* had a great ability to penetrate hardpans. The lowest values for root penetration were found in the landraces 'Kunduru' from Turkey and 'Oued Zenati' from Algeria, and in cultivars developed for favorable conditions, 'Belikh 2', 'Lahn', and 'Cham1'. Breeding using the best durum landraces is important to improve root penetration in soils with hardpans, and thus drought tolerance through better water extraction from deeper layers.

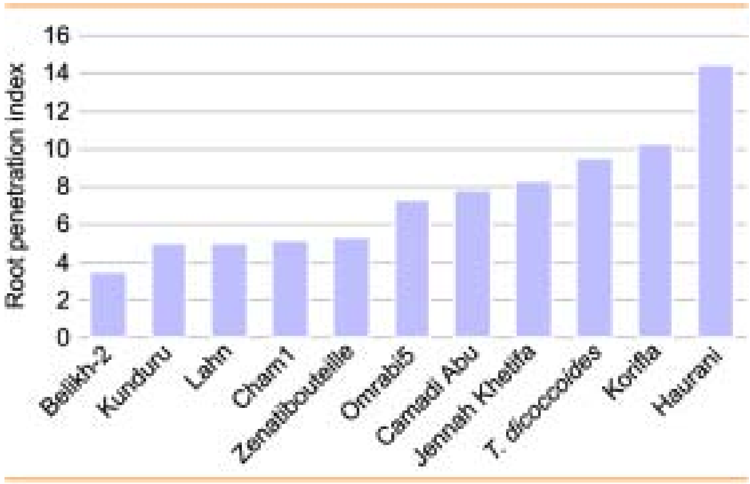


***Fig. 2.4. The ability of roots to penetrate soil hardpans in durum wheat landraces and cultivars, and* Triticum dicoccoides.**

A mapping population of 'Jennah Khetifa' and 'Cham1' was used to study the genetics of root penetration ability. Seven roots of the parent landrace 'Jennah Khetifa' penetrated the paraffin-Vaseline mixture, compared to only three roots of the parent cultivar 'Cham 1'. 'Jennah Khetifa' also produced greater total root dry matter, shoot lengths, and numbers of tillers.

Researchers found one major region of the genome (a quantitative trait locus or QTL) controlling root number and root penetration ability on the long arm of chromosome 6A. This region was closely linked to the locus Xgwm 427b, and accounted for 18.0% of variation in root number and 16.1% for root penetration index. Both these QTLs originated from 'Jennah Khetifa'. The QTL for total root dry weight was linked to the Xgwm11 locus on chromosome 1B, and contributed 14% of variation in root dry weight. The Xgwm11-allele also originated from 'Jennah Khetifa'.

Researchers also found that one QTL on the short arm of chromosome 4B accounted for 18.8% of the variation in plant height. This QTL was probably related to the gene *Rht-B1b*, which was derived from the semi-dwarf wheat variety 'Norin 10', and which has been identified as a gene for reduced height located on chromosome 4BS. 'Jennah Khetifa' is a tall (*Rht-B1a*) and 'Cham1' a semi-dwarf (*Rht-B1b*) genotype. The genomic region for plant height (chromosome 4Bs) is thus different from that of root number and hardpan penetration ability (chromosome 6AL), and so *Rht* genes may not control root traits. The root traits of tall landraces, such as 'Jennah Khetifa', can be introduced into high-yielding semi-dwarf cultivars.

This study showed the importance of QTL analysis in acquiring genetic information on complex traits, such as root traits. A QTL was found to be linked with root penetration ability on the long arm of chromosome 6A in durum wheat. This is a step toward understanding the genetics of root penetration ability, and will speed up the incorporation of this trait in future varieties.

***Durum genotypes derived from crosses with wild* Triticum.**

Development of drought-tolerant synthetic bread wheat genotypes

Plant breeders at ICARDA have developed synthetic bread wheat genotypes that are tolerant to drought by crossing durum wheat with goat grass (*Aegilops tauschii*). They will use these synthetic wheat genotypes to breed improved varieties tolerant to dry conditions.

In the 1994/95 growing season, researchers produced a number of triploid hybrid (hybrids with three sets of chromosomes) crosses of a local durum wheat 'Haurani' and goat grass. They planted the seeds of the hybrids and, after treating plants with colchicine to induce chromosome doubling, they obtained 78 seeds. They also obtained 12 seeds from two untreated hybrid plants. The seed was well-developed and fully viable and, when planted, produced vigorous plants. These have the same genomic structure, AABBDD, as bread wheat.

The A- and B-genome chromosomes of the synthetic bread wheats derive from the durum wheat 'Haurani', which is well adapted to semi-arid regions of Syria. The D-genome chromosomes derive from the *Ae. tauschii* parents, collected from two hot, dry locations in northern Syria (rainfall 300 mm/year) and central Syria (rainfall 162 mm/year).

The new primary wheat synthetics were backcrossed with a spring bread wheat 'Cham 6' and 10 winter or facultative wheats (Fig. 2.5). All F_1 combinations of the parents set seed readily, but the plants subsequently died. Examination of the 'Cham 6' crosses indicated that the necrosis gene alleles – the genes that cause plant tissues to die – from the two *Ae. tauschii* parents have different effects on the plants.

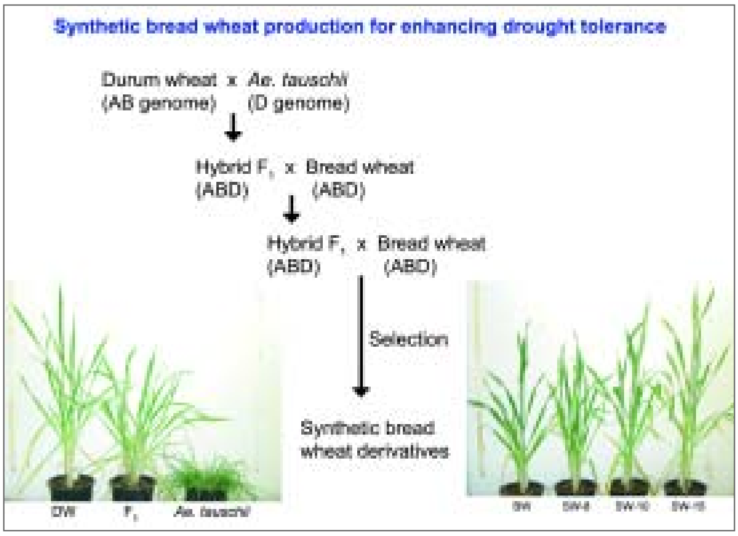


Fig. 2.5. Selecting synthetic bread wheats for drought tolerance from F1 crosses of durum wheat and goat grass backcrossed with bread wheats.

All F_1 plants of 'Haurani'/ICAG 400073 synthetic hybrids died at the seedling stage, whereas F_1 plants of 'Haurani'/ICAG 400709 synthetic hybrids produced a single tiller and plant tissue died off progressively from the lower leaves to the flag leaf. In addition, the plants were completely self-sterile and, when pollinated by 'Cham 6', no seeds set. However, researchers obtained 71 first-generation backcross seeds (BC1) by pollinating emasculated 'Cham 6' plants with pollen from F_1 hybrids. Three synthetic bread wheat phenotypes were produced from the first backcross: a normal phenotype, a phenotype with weak necrosis, and a phenotype with lethal necrosis. From the 'normal' group, researchers selected plants that have short stalks and many spikes for use in breeding programs.

The amount of grain from the selected synthetic bread wheat genotypes varied considerably when tested under four water-

Table 2.2. Comparison of agronomic traits in three synthetic bread wheat genotypes and their spring bread wheat parent ('Cham 6').

Growth stage	Trait	Wheat genotype			
		SW-8	SW-10	SW-15	Cham-6
Heading	Shoot weight (g/m^2)	763	710	1015	715
	Leaf area index	3.35	3.34	3.80	4.33
	Root weight in depth (g/m^2)				
	0-30 cm	115	127	86	129
	30-60 cm	31	27	39	41
Maturity	Biomass (g/m^2)	986	1068	1177	903
	Grain yield (g/m^2)	253	295	226	266
	Harvest index	25.7	27.8	19.2	26.1

New synthetic bread wheat genotypes being tested at ICARDA's Tel Hadya research station.

deficit regimes over two years (Table 2.2). Improved drought tolerance in one genotype (SW-10) may derive from the effect of the goat grass parent (*Ae. tauschii*) and/or durum wheat parent as both are adapted to dry conditions. The genotypes with high biomass did not always produce more grain. This may be because the synthetic bread wheat genotypes have some mechanism for transferring carbohydrate efficiently into the seeds even when soils are dry. The genotypes also accumulate photosynthate after flowering. This means that these genotypes have drought-tolerance genes.

Researchers will now compare the three synthetic bread wheat genotypes to develop genetic markers for drought tolerance, in collaboration with the Japan International Research Center for Agricultural Sciences (JIRCAS).

Facultative and winter wheat varieties for Central Asia and the Caucasus

ICARDA's winter and facultative wheat research program is developing broadly adapted, disease-resistant, high-yielding varieties for the CWANA region; and also facilitating germplasm exchange among NARS. Several cultivars developed jointly by Turkey, CIMMYT, and ICARDA, as part of the International Winter Wheat Improvement Program, are now being released or tested by State Variety Testing Commissions in the region.

Twelve varieties of winter and facultative wheat have been released (Table 2.3) in Central Asia and the Caucasus (CAC). In trials, these varieties consistently out-peformed local checks in terms of yield, grain quality and disease resistance. Some of the new varieties are now grown over large areas.

In Uzbekistan, 'Dostlik' performed particularly well, especially in the drier and salt-affected areas. In 2005, 7500 tons of seed was produced and distributed to farmers in Syrdarya, Djizzak, Samarkand, Bukhara, and Khorezm provinces. By 2006, 'Dostlik' was being grown on over 20,000 ha. New varieties now occupy about 290,000 ha across the CAC – representing a significant increase in wheat production and yield, and major gains in food security.

Table 2.3. Adoption (approximate area in 2006) of recently released winter and facultative wheat varieties in the CAC region.

Country	Variety	Year of release	Area (ha) in 2006
Armenia	Armcim	2006	100
Azerbaijan	Azametli 95	2004	170,000
Azerbaijan	Nurlu 99	2004	65,000
Azerbaijan	Gobustan	2006	5000
Georgia	Mtsheta 1	2002	30
Kazakhstan	Egemen	2007	500
Kyrgyzstan	Djamin	2004	3000
Kyrgyzstan	Zubkov	2004	1000
Kyrgyzstan	Azibrosh	2004	3000
Kyrgyzstan	Almira	2005	15
Turkmenistan	Bitarap	2004	25,000
Uzbekistan	Dostlik	2002	20,000

Characterization of winter wheat cultivars

Researchers characterized 111 wheat varieties from different agroecological zones in CAC, Russia, and Ukraine. They studied growth habit (winter, facultative, spring), growth type (prostrate versus erect), and resistance to yellow rust and leaf rust at ICARDA's experimental farms at Terbol, in Lebanon, and Tel Hadya, in Syria. At Terbol, a two-year off-season summer evaluation clearly separated the varieties into three distinct types: winter, facultative, and spring. In the hot summer conditions at Terbol, the winter cultivars were prostrate, remained vegetative and failed to head, the facultative cultivars headed later than the spring types, and the spring cultivars were erect and headed normally.

Winter wheat cultivars made up 10% of varieties in Turkmenistan, 42% in Armenia, 50% in Uzbekistan, 62% in Russia, 67% in Georgia and southern Kazakhstan, and 100% in Ukraine. There were no winter varieties in Azerbaijan. Spring wheat made up 20% of varieties in Turkmenistan, and 38% in Azerbaijan, but there were none in Armenia, Georgia, southern Kazakhstan, Uzbekistan, Russia, or Ukraine. All countries except Ukraine had facultative wheat varieties. The main factors affecting the type of wheat cultivars are latitude and altitude. The frequency of winter wheat varieties increases at higher latitudes and altitudes (Fig. 2.6).

Spring wheats are sown in the fall between latitudes 35°N and 40°N (Azerbaijan and Turkmenistan). In Azerbaijan, the main wheat-growing areas are at low altitudes (50 to 750 masl) and have mild winters. For high yields, wheat needs to be irrigated. Facultative and winter wheats grow well in irrigated or high-rainfall areas with mild winters, for example, in Armenia.

The spring wheat type grew successfully in areas where the average temperature in January was either below –7°C as spring planting (e.g. Northern Kazakhstan) or over 4°C as fall planting, while winter-type wheats were distributed mainly in areas with –7°C to 4°C. The results indicate that geographi-

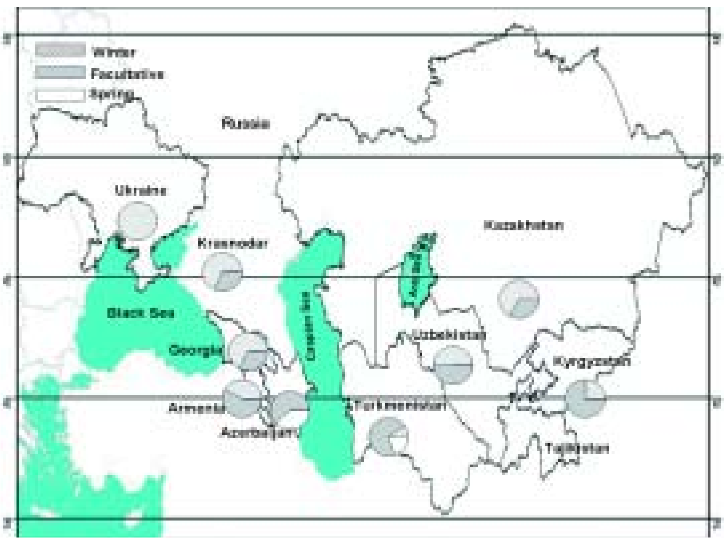


Fig. 2.6. Proportions of winter, facultative, and spring wheat varieties in Central Asia and the Caucasus, Russia, and Ukraine.

cal variation in growth habit is closely related to temperatures in winter. High-altitude areas, with cold winters, require winter hardy varieties, although most of the wheat varieties grown in the region are classified as fall planted winter or facultative type.

Early maturing winter wheat line suitable for agricultural intensification in countries in Central Asia and the Caucasus (seed production field in Kyrgyzstan).

Overall, 24% of the 111 wheat cultivars characterized were resistant to yellow rust and 4% were resistant to leaf rust. Cultivars from Azerbaijan (22%), Kazakhstan (23%), Uzbekistan (37%), Turkmenistan (20%), Ukraine (67%), and Russia (26%) showed resistance to yellow rust but all varieties in Armenia, Georgia, and Kyrgyzstan were susceptible. Varieties from Kazakhstan (8%), Uzbekistan (25%), and Russia (2%) were resistant to leaf rust. Only one variety, 'Yuzhnaya 12', from Kazakhstan, was resistant to both yellow rust and leaf rust. The characterization classified 111 wheat cultivars from CAC, Russia and Ukraine into three types: spring, facultative and winter wheat. The study also identified cultivars that are resistant to yellow rust and leaf rust. Researchers will now use these cultivars as parent material in programs to improve resistance to diseases and breed wheat varieties adapted to the range of agroclimatic conditions in wheat-growing areas in the region.

Ug99: a serious threat to global wheat production

For several decades wheat stem rust has been controlled worldwide using genetically resistant wheat varieties, and this has reduced the impact of this fungal disease. Changes in the virulence of the rust have rendered some types of resistance ineffective. However, resistant cultivars have generally been developed before significant damage was done.

Worldwide, stem rust had been largely under control but there are several areas ('hot-spots') where it has suddenly reappeared. From East Africa a new threat has emerged and resistance has been overcome by a new race of the disease known as Ug99. Rust spores travel long distances, so it is only a matter of time when Ug99 would cross to the Arabian Peninsula. From there it is very likely to enter the Near East, South Asia and eventually East Asia and the Americas. ICARDA and CIMMYT launched the Global Rust Initiative (GRI) in 2005 to deal with this new threat (see www.globalrust.org for more details).

Stem rust could become a major threat in several countries including Yemen, Sudan, Egypt and Saudi Arabia. Large losses would greatly increase the cost of imports and threaten the food security of millions of poor consumers whose main staple is wheat. The GRI is planning a series of projects to systematically eliminate the world's vulnerability to Ug99, and to maintain or enhance resistance to the widespread leaf and yellow rusts.

The international spread of airborne rust diseases will be monitored in the field. In addition, researchers will study the epidemiology of rust movement and will analyze rust races to determine the origin of new, evolving pathotypes. This will provide an early warning system for farmers growing potentially susceptible cultivars.

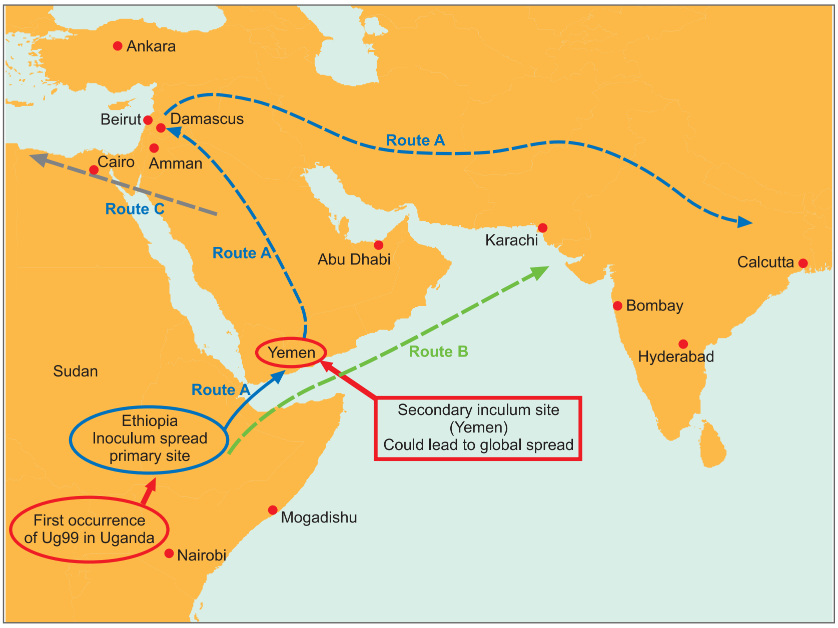


Fig. 2.7. Major wheat-growing areas and the occurrence and spread of Ug99. Its expected path is based on the movement of the virulent yellow rust Yr9 in the 1990s, which followed Route A. Ug99 was first recorded in Uganda in 1999, from where it moved to Kenya and Ethiopia in 2005 and Yemen in 2006. Scientists perceive that winds could spread the rust further along Route A, and along Routes B and C.

Knowledge of which resistance genes are effective in a region will help breeders to incorporate and accumulate (pyramid) these genes in wheat germplasm, and so develop cultivars that sustain resistance for longer. It may be necessary to test cultivars in rust hot-spots outside the region, as the virulence for certain resistance genes may already be present in the rust population.

Monitoring Ug99 evolution and migration is a high priority for four reasons. First, stem rust spores can move freely over long distances. Second, several current cultivars have resistance genes that are specific to particular rust races, and so resistance may be short-lived. Third, the same cultivars are grown over large areas in several countries, so impacts could be huge. Fourth, the same resistance genes to several rusts are deployed in multiple cultivars grown in different countries. In 2006, researchers from ICARDA, CIMMYT and the Cereal Rust Laboratory at Minnesota (USDA-ARS) worked together to assemble an international stem rust trap nursery. This was used to study the variability of stem rust in nature as well as the presence or absence of Ug99. The nursery consists of 60 cultivars and breeding lines of bread wheat, durum wheat, and barley, and was sent to collaborators in the Nile Valley region, East Africa, North Africa, West Asia, Central Asia, the Caucasus, and Latin America. Ug99 was not detected at 17 primary testing sites in Kenya, Ethiopia, Yemen, Egypt, Eritrea, and Sudan. Neither was it detected in the network of secondary testing sites in 19 countries in North Africa, Latin America, West, Central, and South Asia.

A wheat plant damaged by rust.

Rust samples were also collected and analyzed at special laboratories. Ug99 was detected in samples collected along Route A (Fig. 2.7) in September and October 2006 in Yemen and Sudan. A press release entitled "Dangerous wheat disease jumps Red Sea: Devastating fungal pathogen spreads from eastern Africa to Yemen, following path scientists predicted" was internationally distributed. The predicted paths (Fig. 2.7) are being carefully monitored and steps are being taken by national programs and the international community to limit the spread of Ug99. GIS maps are being developed to establish an early warning system.

First sources of resistance to Hessian fly in Syria

The Hessian fly, *Mayetiola destructor*, is a major pest of wheat in North Africa, North America, southern Europe, and northern Kazakhstan. The most practical solution to this problem is to grow wheat varieties that are not affected by the fly. So, researchers at ICARDA are studying synthetic varieties of wheat, and its wild relatives from Europe, West Asia, and North Africa, to find resistant sources.

In 2006, researchers screened 617 lines and accessions of wheat and its wild relatives (*Aegilops* and *Triticum* species) for their reactions to Hessian flies collected from Lattakia, in Syria. They put plants infested with mature pupae of the Hessian fly alongside seedlings at the one-leaf stage in cheesecloth tents. When the females emerged, they were allowed to lay eggs for two days. Twenty days after the eggs hatched, the plants were examined.

Plants that were not resistant were infested with live larvae, dark green, and stunted. On 29 of the 280 *Aegilops* accessions (Table 2.4), all the newly-hatched larvae were dead. This showed that these accessions are resistant. The resistant plants were well developed and the leaves were light green. Most of the resistant *Aegilops* accessions came from Morocco (Table 2.4). *Aegilops ventricosa* and *Ae. ovata* had the highest proportion of resistant accessions: 67% and 36%, respectively.

Table 2.4. *Aegilops* species resistant to Hessian fly in Syria.

Species	Accession number	Country of origin
Ae. ventricosa 401430	AECO96-8	Morocco
Ae. ovata	AECO96-17	Morocco
Ae. ovata	AECO96-19	Morocco
Ae. ovata	AECO96-21	Morocco
Ae. ovata	AECO96-22	Morocco
Ae. ovata	AECO96-23	Morocco
Ae. ventricosa	AECO96-28	Morocco
Ae. ventricosa	AECO96-31	Morocco
Ae. ovata	AECO96-43	Morocco
Ae. ovata	AECO96-47	Morocco
Ae. ovata	AECO96-49	Morocco
Ae. ovata	AECO96-54	Morocco
Ae. ovata	AECO96-59	Morocco
Ae. ovata	AECO96-61	Morocco
Ae. ovata	AECO96-62	Morocco
Ae. ovata	AECO96-64	Morocco
Ae. triuncialis	AECO96-68	Morocco
Ae. ventricosa IC 400536	AECO96-74	Morocco
Ae. longissima 400541	AECO96-78	Morocco
Ae. ovata 89E 124	AECO96-86	France
Ae. ovata 88E 211	AECO96-87	France
Ae. ovata 89E 149	AECO96-88	France
Ae. ovata 89E 150	AECO96-89	France
Ae. sp.	AECO96-100	Morocco
Ae. geniculata	Recip99-1	Unknown
Ae. speltoides var. speltoides	IG46560	Syria
Ae. speltoides var. speltoides	IG46566	Syria
Ae. tauschii var. strangulata	IG46897	Iran
Ae. tauschii	IG46911	Iran

Table 2.5. Synthetic derived bread wheat lines resistant to Syrian Hessian fly under greenhouse conditions.

Synthetic derived bread wheat lines	Cross/pedigree	Percent resistant plants
SynBW-AYTSYN-27	Cupra-1/3/Croc1/Ae. squarrosa (224)//2*Opata	84
SynBW-AYTSYN-71	Cndo/R143//Ente/Mexi 2/3/Ae. squarrosa (Taus)/4/ Weaver/5/SOM/6/Lagos-4	84
SynBW-AYTSYN-78	Cndo/R143//Ente/Mexi 2/3/Ae. squarrosa (Taus)/4/ Weaver/5/SOM/6/Lagos-4	85
Synthetic-YT 02- 9	Altar 84/AAe. squarrosa (Taus)//Opata	99
Nasma (susceptible check)		0
Cando (resistant check)		100

Only four of the 191 synthetic derived bread wheat lines tested were resistant (Table 2.5). The resistant *Aegilops* accessions and synthetic derived bread wheat lines identified are being exploited by ICARDA's durum and bread wheat breeding programs in order to transfer Hessian fly resistance to wheat.

TILLING: a powerful strategy for detecting mutations

ICARDA researchers have recently begun to use a new 'reverse genetics' strategy known as TILLING (Targeting Induced Local Lesions In Genomes). Reverse genetics techniques are used to find or to produce mutations that help identify the function of a gene or protein.

TILLING involves inducing point mutations in DNA using chemicals, then rapidly screening the mutants (Fig. 2.8). Key to this is the analysis of plant phenotypes.

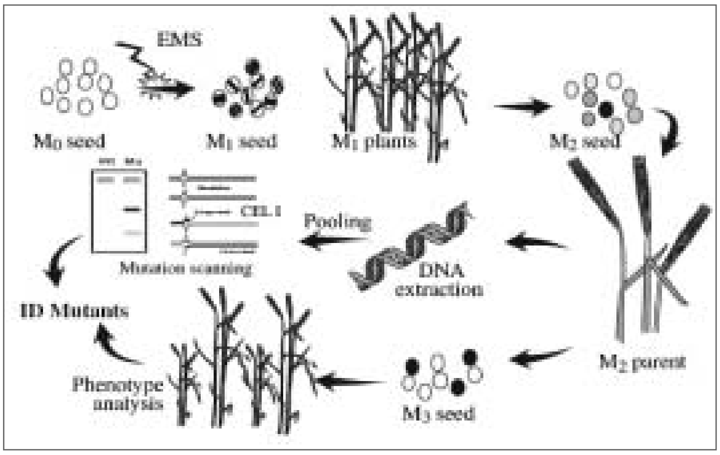


Fig. 2.8. General procedure for creating a structured mutant population. M0 seed is treated to cause mutations. Researchers grow this first mutated (M1) seed into M1 plants, which produce M2 seed. A single M2 seed is taken from each M1 plant and grown into M2 plants. DNA is extracted from each M2 plant and its M3 seed, and archived for analysis and phenotyping. 'Reverse genetics' screening is performed on pooled DNA extracted from M2 plants and 'forward genetics' screening on M3 families. EMS = ethyl methane sulfonate. ID Mutants = identified mutants.

In 2006, researchers at ICARDA developed a TILLING population for the Danish barley cultivar 'Lux' – using sodium azide to induce point mutations. When they compared the phenotypes of third-generation mutant plants (M3 plants, Fig. 2.8) with the parent cultivar, researchers found over 3.5% lethality. This means that more than 3.5% of the M3 plants were abnormal and would not survive to reproduce. The photo on left shows a white M3 plant containing no chlorophyll, a clear example of a mutation.

M3 plants in a mutated population of the barley cultivar 'Lux', which was created (using TILLING) to detect mutations. More than 3.5% were found to be abnormal when compared with unaltered plants of the parent cultivar based on four easily visible traits. The abnormal white plants produced no chlorophyll.

The value of using the TILLING technique in the detection of induced point mutations in the 'Lux' population was demonstrated by screening this population with two different dehydrin genes. This identified five independently induced mutations within this population of 9575 mutagenized barley plants. The results also showed that the DNA sequencer system called ABI Prism 377 was suitable for this type of use, as it detected point mutations in the 'Lux' population and within the two dehydrin genes.

In the next step, researchers will backcross the mutated lines to reduce background mutations and to investigate the phenotypic effects of the mutated gene.

Farmers' choice – the key to selecting better lentil varieties

In rainfed farming systems in South Asia, West Asia, and North and East Africa, lentil is a major source of protein and nutrients for the poor. Lentil straw is an important animal feed. In addition, lentils sequester carbon, and improve soils by adding nitrogen and organic matter.

Because lentils are so important for food, animal feed, and soil health, ICARDA researchers are working with national crop improvement programs to improve lentil varieties. Although several improved varieties of lentil have been released in many countries over the past few decades, farmers have been slow to adopt them. The reasons vary. Sometimes the new varieties are poorly adapted to farmers' particular environments, or are vulnerable to pests and diseases. In other cases the seed distribution systems are ineffective, or there are no extension services to help farmers learn how to grow the new varieties. Quite often, the preferences of farmers and consumers have been ignored.

To select varieties that best meet farmers' needs, ICARDA researchers, together with their colleagues in national agricultural research systems (NARS), have now adopted a 'farmer-participatory' approach to selecting and disseminating improved lentil cultivars. This approach has many advantages. Farmers select varieties adapted to their specific conditions and needs. This means more varieties – suited to many different farming niches – will be grown, thus increasing biodiversity. In addition, farmers are more likely to recommend, and give or sell seed, to their neighbors, speeding up the adoption of new varieties and impact at farm level.

Farmers in Eritrea select lentil lines from ICARDA-supplied germplasm.

Most importantly, this approach taps into farmers' own skills, honed over generations, in choosing varieties that suit them best. The lentil breeding program at ICARDA involves farmers in selecting promising materials right from the start. The breeding program thus benefits from farmers' first-hand knowledge of crops and cropping systems, local soil and weather conditions, and consumer and market preferences. This means the program is more likely to produce varieties that farmers want, need, will use, and will pass on to other farmers.

Participatory varietal selection: how it works

Over the past few years, the participatory varietal selection (PVS) approach has been tested in traditional lentil-growing areas in Syria, Yemen, Eritrea, Nepal, and Bangladesh. The first step is the Farmer Initial Trial (FIT). These take place in two or three villages. The farmers grow 30-50 improved landraces and elite breeding lines developed through cross-breeding, inter-planted with the local variety they normally plant, using their usual cultivation methods. When the plants are mature, farmers, researchers, NGO staff, and extensionists score the lines on characteristics such as time to maturity, canopy height, seed characteristics, seed and biomass yield, and so on. The grain yield and biomass are measured after harvest.

The next step is the Farmer Advanced Trial (FAT). For these trials 10-12 lines are selected on two criteria: yield and farmers' ratings. The farmers' key criterion in selecting lentil varieties is the quality of the grain. Other preferred traits are strong plant stands, resistance to diseases and, in the case of Syria, large amounts of straw.

The selected lines are then grown in large plots in four to eight villages. These lines are evaluated in the same way as for the initial trials and the best two or three lines go on to the next step, the Farmer Elite Trial (FET). These last trials take place in eight or more villages and incorporate a seed multiplication component. The final stage is to propose the varieties for release. This means entering them in the state variety testing program or getting them included in national on-farm trials.

Participatory varietal selection of lentil

In three very different villages in Yemen, farmers selected five lines for testing, out of an initial 50 genotypes. Three of the lines yielded nearly double the amount of seed and two-thirds more biomass than the local variety. In Eritrea, farmers selected two lentil lines, ILL 7978 and ILL 10013, from the 75 lines tested. Seed of ILL 7978 is being multiplied and will soon be released. In Nepal, farmers were looking for lentil that matures early and would fit into the local rice–lentil–maize cropping system. They selected ILL 7164 and ILL 8006, both early-maturing varieties. In Bangladesh, farmers in four very different environments chose X95S-136, a lentil line that is highly resistant to rust and *Stemphylium* blight, widely adapted to different conditions, and produces high yields. The line has recently been released under the popular name 'Barimasur-5' in Bangladesh. Finally, in Syria, five green lentil and seven red lentil lines, selected in FIT and FAT, are going forward to on-farm trials.

The participatory varietal selection approach is proving very effective for improving lentil. It is a method that works particularly well for crops that are grown in marginal environments. For such crops, most seed is saved on-farm, as formal seed distribution systems are either non-existent or not effective. Participatory programs have the additional advantage of encouraging informal farmer-to-farmer systems that distribute seed of the new cultivars, which promotes fast adoption.

Combining resistance to common diseases in lentil

Biotic and abiotic stresses cause substantial yield losses to lentil farmers worldwide. Among the biotic stresses, diseases – mainly caused by fungi – are the most devastating. *Fusarium* wilt, rust, and *Ascochyta* blight are particular problems in a wide range of environments throughout the world. Other diseases, such as root rots, stem rots, *Botrytis* blight, and *Stemphylium* blight, are more localized. In most places, lentil is susceptible to several diseases. This means that lentil varieties are needed that are resistant to not just one disease, but to all the common diseases within a particular production zone.

Several national and international research organizations worldwide are gene mining – testing germplasm held in genebanks to identify genes that confer resistance to various diseases. Many of the 10,500 cultivated and wild relatives of lentil in ICARDA's lentil genebank harbor genes for resistance to diseases. For example, researchers recently screened 1500 accessions and found 34 new sources of resistance to vascular wilt.

Techniques are now available to screen germplasm for susceptibility to common diseases. All new germplasm and breeding lines at ICARDA's Tel Hadya station are now screened systematically for resistance to *Fusarium* wilt. National agricultural research systems also systematically screen for common diseases, for example, for rust in Dholakuan and Pantnagar, in India, and Debre Zeit, in Ethiopia, and for *Ascochyta* blight in Horsham, Australia, and Islamabad, in Pakistan.

The resistant lines are now being used in breeding programs. Lines ILL 4605 and ILL 6002 are important donors for resistance genes for rust and *Stemphylium* blight. ILL 5883, ILL 6994, and many other lines are sources of resistance to vascular wilt. Some progress has been made in developing resistance to more than one disease by incorporating genes from several different parents.

Researchers in national programs are selecting resistant lines from appropriate germplasm and breeding materials supplied by ICARDA. They are looking for sources of resistance to the most common diseases in their area. For example, in Morocco and Ethiopia researchers need to develop lentil with combined resistance to rust and wilt; in Pakistan to *Ascochyta* blight and wilt; in northern India and western Nepal to wilt and rust; in eastern India, Nepal, and Bangladesh to rust and *Stemphylium* blight; and in West Asia to vascular wilt and other root diseases.

A lentil field devastated by rust in the Indian state of Bengal.

New lentil cultivars that are resistant to more than one disease are already being grown by farmers. For example, in Ethiopia, farmers are growing 'Alemaya', a new variety resistant to rust and wilt. In Morocco, farmers are growing 'Abda' and 'Chaouya', new varieties resistant to rust and wilt and, in Bangladesh, 'Barimasur-4', resistant to rust and *Stemphylium* blight, and 'Sital', resistant to wilt and root rots.

Assessing resistance to vascular wilt in large-seeded lentil

Lentil vascular wilt, caused by the fungus *Fusarium oxysporum* f. sp. *lentis*, is one of the most important diseases affecting lentil production worldwide. Use of host plant resistance is the most practical and economic way of managing the disease and reducing yield losses.

Previous work at ICARDA has exploited resistance sources in small-seeded red lentils and several resistant varieties have been released. However, there are few sources of resistance in large-seeded green lentils and resistant genotypes are being sought.

Researchers therefore screened a collection of 257 large-seeded lentils, including 41 breeding lines and 216 landraces originating from 32 countries, in a well-developed wilt-sick plot at Tel Hadya, Syria. The collection was evaluated during the 2005/06 season in small replicated rows and compared with 'Precoz', a susceptible cultivar from Argentina.

Researchers have identified large-seeded lentil lines with a high level of resistance to lentil vascular wilt disease.

Disease severity was evaluated three times from flowering/podding to maturity as the percentage of wilted plants. The final disease score for each accession was the highest percentage recorded in any of the replications across evaluations. If less than 20% of plants were wilted, the accession was considered to be resistant.

Researchers found that 21% of the accessions were resistant. The greatest numbers of resistant accessions were found in materials from Chile (42% of the accessions tested) and Spain (12%), and in breeding lines developed at ICARDA (34%). There was no resistance in the 58 accessions from Iran and Syria, while only one of the 21 Turkish accessions was resistant.

The resistant lines will be re-evaluated, and confirmed sources of resistance will be international public goods, shared with lentil breeding programs worldwide.

First sources of resistance to lentil leaf weevil

The lentil leaf weevil, *Sitona crinitus,* is the main insect pest of lentil in West Asia and North Africa. Adult weevils harm seedlings but the worst damage is caused by the larvae. These feed on the nitrogen-fixing nodules, which means that plants cannot fix atmospheric nitrogen. Highly infested plants yield 17.7% less straw and 14.1% less grain.

Insecticides to control *Sitona* are effective but, because they are expensive, farmers do not use them. The most practical solution is to grow lentil varieties that are not affected by the weevil. However, to date, researchers have found no varieties of cultivated lentil that are resistant. So, they are now searching for resistant lines in wild relatives of lentil.

To do this, between 2000 and 2006, researchers screened 315 accessions for resistance to *Sitona* under field conditions at Tel Hadya, Syria. They found a large variation in the percentage of damaged nodules among accessions. Eight accessions (Table 2.6) had significantly fewer damaged nodules (10% or less) than the susceptible control (56%). All originate from West Asia, either from Turkey or Syria. Researchers will cross these lines to develop new lines of lentil that are resistant to the weevil.

Table 2.6. Variation in damage to nitrogen-fixing nodules in wild relatives of lentil by lentil leaf weevil, *Sitona crinitus*.

Accession	Species	Origin	Percent nodules damaged
ILWL 110	*Lens nigricans*	Turkey	9
ILWL 166	*Lens odemensis*	Syria	10
ILWL 136	*Lens ervoides*	Syria	8
ILWL 203	*Lens odemensis*	Turkey	10
ILWL 207	*Lens ervoides*	Croatia	10
ILWL 245	*Lens orientalis*	Syria	10
ILWL 254	*Lens odemensis*	Syria	10
ILWL 258	*Lens ervoides*	Turkey	9
Susceptible control	*Lens culinaris*	Syria	56

Genetic variation in cultivated and wild lentil

In 2006, ICARDA researchers conducted a study to investigate the relationships between cultivated lentil and its wild relatives. The study also aimed to shed light on how lentil was domesticated.

Researchers sequenced genetic markers. They chose 135 accessions of cultivated lentil and 179 of wild *Lens*. These represent the entire geographic range of the genus. First they extracted DNA from plants which they grew in the greenhouse. Then, they compared genomic sequences in *Medicago truncatula* with those in *Arabidopsis thaliana* to determine the areas to sequence in order to locate the genetic markers. For all the accessions, they amplified and sequenced the DNA strands using the polymerase chain reaction technique, and compared the gene marker sequences. An analysis of gene length, number of segregating sites, number of haplotypes, haplotype diversity, nucleotide polymorphism, and nucleotide diversity determined the extent of genetic variation. Finally, to show the genetic relationships between accessions, they constructed a neighbor-joining tree.

Initially, six genes were sequenced for 3775 base pairs. On average genes had 14 single-nucleotide polymorphisms (SNPs) and 6.5 haplotypes. Wild species had more SNPs and more haplotypes than cultivated lentil. This means they are more genetically diverse. Of the wild lentil, *L. culinaris* subsp. *orientalis* and *L. lamottei* showed the most variation (Fig. 2.9).

The neighbor-joining tree diagram shows the genetic relationships between species. They formed seven distinct clusters (Fig. 2.10). Four species, *L. ervoides*, *L. nigricans*, *L. lamottei*, and *L. culinaris* subsp. *odemensis*, each formed separate clusters. Mixtures of *L. culinaris* subspecies *culinaris* and *orientalis* formed two other clusters. One of these contained accessions from West Asia and the second contained accessions from North Africa, Central Asia, and Europe. The last cluster was made up of three *L. culinaris* subspecies from West Asia: *culinaris*, *orientalis*, and *tomentosus*.

Gene sequencing showed that the *Lens* genus is genetically quite diverse and promises to be very effective for studying diversity in germplasm collections and patterns of domestication. The initial results

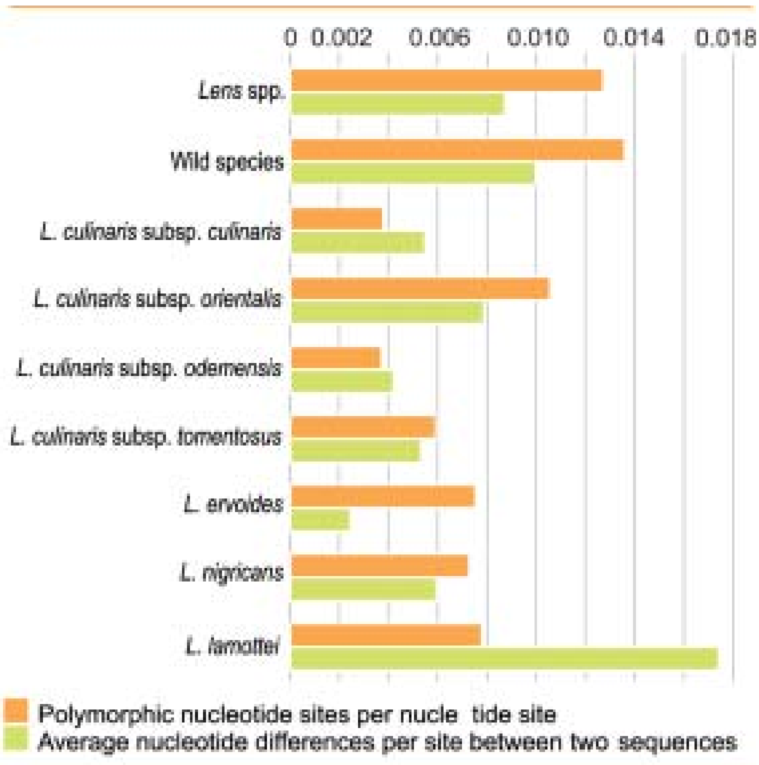


Fig. 2.9. DNA sequence diversity in cultivated and wild accessions of Lens.

indicate that lentil became less genetically diverse with domestication. Groups of lentil that are genetically related show quite clearly on the neighbor-joining tree even though only a few gene sequences were analyzed.

Analyzing more gene sequences should allow more detailed relationships to be identified. These relationships, together with information on human migration and trade patterns, will provide valuable insights into lentil domestication.

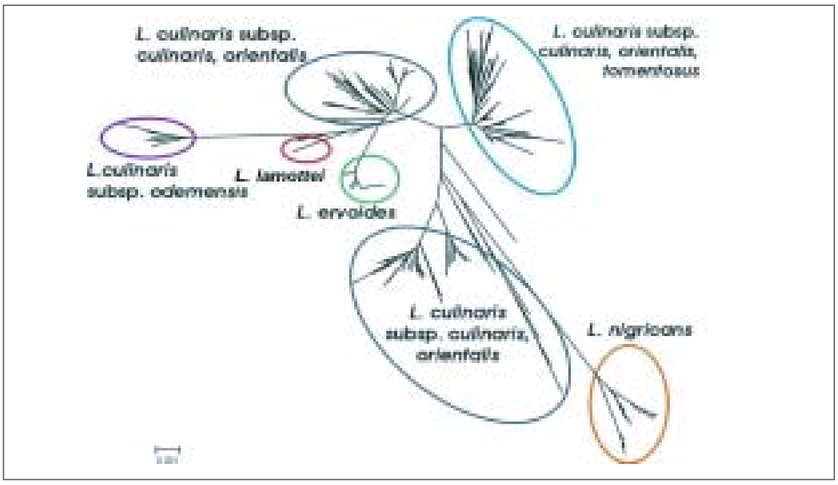


Fig. 2.10. Neighbor-joining tree of relationships between **Lens** *species.* **L. culinaris** *subsp.* **culinaris** *is domesticated; all other taxa are wild.*

Molecular characterization of wild and cultivated lentil

Genetic diversity within a crop species and its wild relatives is an advantage because plant breeders can use genes from different lines, such as genes for disease resistance or tolerance to drought, to develop new, improved varieties. In 2006, researchers profiled genetic diversity in lentil accessions from 15 countries and from ICARDA's genebank (Table 2.7) using 14 lentil microsatellite primers previously developed by ICARDA. The accessions comprised 57 of cultivated lentil and 52 wild accessions from three subspecies (29 *orientalis*, 19 *odemensis*, and 4 *tomentosus*).

The size of the amplified fragments was 109 to 387 base pairs, and 244 alleles were detected. Twelve of the 14 microsatellite markers showed a

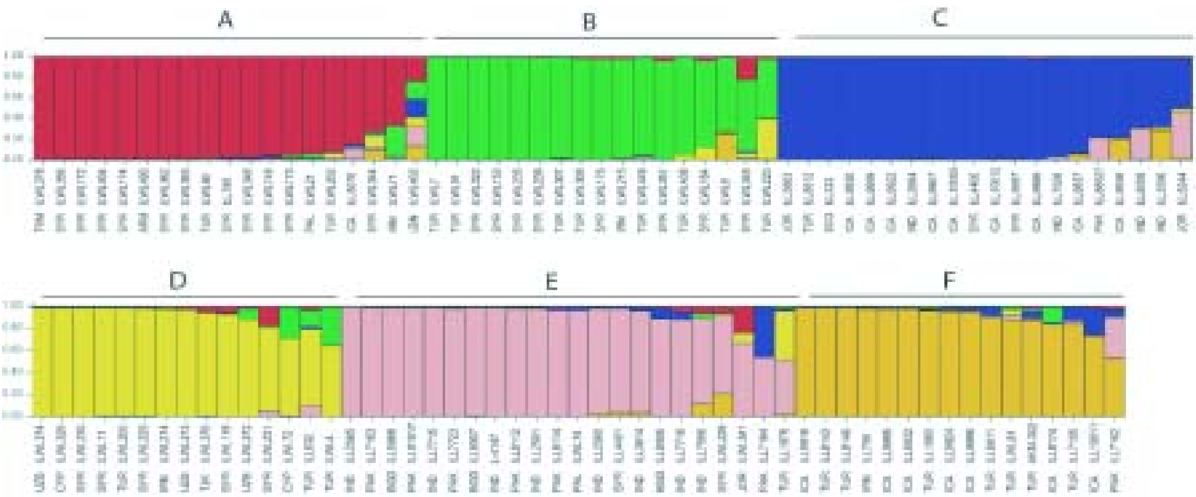


Fig. 2.11. Genetic diversity in the 109 lentil accessions studied at K=6 using structure software. The country codes (see Table 2.7) appear below the accession numbers. The analysis identified six clusters: wild lentil collected in clusters A, B and D; and cultivated lentil in clusters C, E and F. Accessions from South Asia collected in E in two genepools in cultivated lentil.

high value of gene diversity. The mean value of gene diversity in the wild accessions was 0.69 (range 0.17 to 0.93), and in cultivated accessions 0.66 (range 0.03 to 0.89). The number of alleles per marker varied from 4 to 29, and the numbers were greater in wild (10.9) than in cultivated lentil (8.1). An average of 9.5 alleles per locus was observed.

Researchers then used structure analysis to identify relationships among the 109 accessions. Most of the wild accessions were found in three populations (A, B, and D; Fig. 2.11), while the cultivated lentil accessions were found in populations C, E, and F. The majority of accessions in population E originated from South Asia (India, Bangladesh, and Pakistan). ICARDA breeding lines were distributed with Turkish accessions in population C and with different origins in population F. The study of lentil diversity in this mini-core collection and using microsatellite markers indicated that wild and cultivated lentils were separated in two genepools. These alleles will be used in the future to develop improved varieties.

Table 2.7. Genetic diversity in 109 wild and cultivated lentil accessions from 15 countries and from ICARDA's genebank.

Origin	Country code	No. of accessions	
		Wild	Cultivated
Turkmenistan	TKM	1	0
Syria	SYR	24	4
Armenia	ARM	1	0
Turkey	TUR	14	9
ICARDA	ICA	0	18
Iran	IRN	3	1
Lebanon	LBN	1	0
Jordan	JOR	1	2
Serbia & Montenegro	SCG	0	1
India	IND	0	12
Pakistan	PAK	0	7
Uzbekistan	UZB	3	0
Cyprus	CYP	1	0
Tajikistan	TJK	1	0
Bangladesh	BGD	0	3
Palestine	PAL	2	0
Total		52	57

New kabuli chickpeas for Ethiopia

ICARDA's chickpea breeders have developed a range of improved materials, that have been assembled into nurseries and distributed to partners worldwide. National research programs (often in partnership with ICARDA) test this material, to identify genotypes adapted to agroecological zones in their respective countries. This approach has helped identify improved varieties for a range of environments, and also strengthened national research programs in developing countries.

Chickpea in Ethiopia is a good example. Researchers at the Debre Zeit Agricultural Research Center have been evaluating elite chickpea nurseries from ICARDA. The materials have been tested for several seasons in different agroecological zones. Two lines, in particular, performed consistently well in the mid- to high-altitude areas where the bulk of Ethiopian chickpea is produced. Both lines were part of an ICARDA international screening nursery distributed to several countries in 1998.

One line, known as FLIP 97-263C, was bred at ICARDA's Tel Hadya research station in 1994. It was tested for six years in Ethiopia: three years on research stations, and three years on-farm, at nine locations across the country, yielding 25% more than the local check variety. The second line, FLIP 97-266C, was tested in 20 trials over three years, at eight locations. It gave a seed yield of 2747 kg/ha, 28% more than the local check variety and the highest in the trials.

In 2006, the Ethiopian government released both varieties for cultivation in mid- to high-altitude, semi-moist agroecological zones of the country. They were named 'Ejere' (FLIP 97-263C) and 'Teji' (FLIP 97-266C).

These are the first market-targeted kabuli types to be released in Ethiopia. Apart from their high yield and adaptation, the two varieties have a number of desirable characteristics. Both have large seeds (100-seed weight of 37.2 and 38.1 g), and therefore fetch high prices on local and export markets. Both are resistant to *Fusarium* wilt disease, which is a major constraint in these areas. And both have a plant height (Ejere 34 cm, Teji 40 cm) suitable for mechanical harvesting.

Ethiopian institutions are now multiplying seed in large quantities, with support from ICARDA. This will ensure that high-quality seed is widely available. Farmer feedback on the field performance and profitability of the new varieties has been very positive, and adoption is expected to increase rapidly.

Better screening techniques for chickpea resistance to *Ascochyta* blight

Ascochyta blight is one of the most important diseases of chickpea worldwide. Host plant resistance is the major control method and the cornerstone of any integrated disease management package. To screen for resistance to *Ascochyta* blight, plants need to be artificially and uniformly inoculated with the fungus. Large quantities of spore suspensions prepared from fungal cultures grown on synthetic media are therefore required for field screening. This process is time-consuming and expensive for research programs in developing countries. ICARDA researchers have been working to develop more affordable and efficient methods of producing and applying inoculum.

Developing affordable and effective ways of screening for* Ascochyta *blight in chickpea: a trial comparing different methods of applying the disease-causing fungus at Tel Hadya, Syria.

A split-split-plot experiment was conducted to improve disease screening at ICARDA's principal research station at Tel Hadya in Syria. Researchers tested different cultivars (the highly susceptible ILC 263 and moderately susceptible ILC 482), different types of inoculum (infected seed, infected crop debris, and a spore suspension derived from infected seed), and different inoculum application times (early, middle, and late application) following plant establishment. They also used a new disease index that considered both disease severity (on a 1-9 scale) and disease incidence (0-100%). Researchers found significant effects due to cultivar, inoculum type and application time, and also significant interactions between the three. This showed that choice of inoculum and time of application were both important. Infected crop debris caused the highest levels of disease at all application times. Early application of the spore suspension caused the second-highest disease level. Infected crop debris may continuously supply inoculum and sustain infection throughout the parasitic phase of the disease cycle.

There were clear advantages of an early application of infected crop debris when screening chickpea for *Ascochyta* blight resistance. This method is affordable and readily applicable for screening in developing countries.

New resistance to leaf miner and cyst nematode in chickpea

Chickpea is an important food legume in West Asia and North Africa, but destructive pests such as the chickpea leaf miner and cyst nematodes cause large crop losses. Although insecticides and nematicides are effective, farmers seldom use them because they are expensive and unsafe. A better alternative is to develop chickpea varieties that are resistant to these pests. ICARDA's research has shown that just a few cultivated chickpea varieties are resistant to leaf miner, and none are resistant to chickpea cyst nematode.

Dr Mustafa El-Bouhssini (left), Entomologist, and Dr R.S. Malhotra, Senior Chickpea Breeder, examine improved chickpea lines for leaf miner resistance at Tel Hadya, Syria.

Breakthrough in developing chickpea resistant to leaf miner

The few ICARDA chickpea accessions (landraces) that are resistant to chickpea leaf miner either have small seeds or poor agronomic characteristics. So researchers successfully crossed varieties with resistance to leaf miner with varieties that have good agronomic characteristics. The transfer of leaf miner resistance from landraces to improved varieties of chickpea is a breakthrough in chickpea breeding.

Researchers selected the best seven lines (Table 2.8) and seeds of these are now being multiplied for sharing with NARS in countries where chickpea is prone to leaf miner infestation. The first set was sent to Mexico for evaluation in the 2006/07 season.

Chickpea resistant to cyst nematode

ICARDA reseachers tested accessions of wild relatives of chickpea for resistance to cyst nematode. They found some annual species that were resistant and just one that could be crossed with a domesticated chickpea.

Over the years, further crosses have produced two promising typical kabuli chickpea lines resistant to cyst nematode. The bulked seed from each of these progenies has been evaluated (Table 2.9) and seed is available for use in breeding programs.

Table 2.8. Characteristics of seven chickpea lines resistant to leaf miner.

Line no.	Accession number	Pedigree†	Leaflet size	Seed yield (kg/ha)	100-seed weight (g)	Leaf miner reaction (1-9 scale)‡
75	FLIP 2005-1C	ILC 3805/ ILC 3397	Normal	1407	34.0	3
109	FLIP 2005-2C	ILC 3805/ ILC 5309	Intermediate	2045	21.0	3
136	FLIP 2005-3C	ILC 5901/ ILC 3397	Very small	1446	33.8	2
137	FLIP 2005-4C	ILC 5901/ ILC 3397	Intermediate	1076	33.2	2
142	FLIP 2005-5C	ILC 5901/ ILC 3397	Very small	1406	32.2	3
181	FLIP 2005-6C	ILC 5901/ ILC 5309	Intermediate	1939	25.4	3
199	FLIP 2005-7C	ILC 3397/ ILC 5309	Normal	1353	45.0	4

†ILC 5901 and ILC 3805 = resistant, ILC 5309 = moderately susceptible, ILC 3397 = susceptible

‡ 1 = most resistant, 9 = highly susceptible

Table 2.9. Characteristics of two new chickpea lines resistant to cyst nematode.

Accession number	Days to flowering	Days to maturity	Plant height (cm)	100-seed weight (g)	Nematode resistance score† (1-9 scale)	Seed yield (kg/ha) in normal conditions	Seed yield (kg/ha) in nematode infested plot	Flower color	Seed color	Seed type
FLIP 2005-8C	66	98	32	24	3	944	1037	White	Beige	Kabuli
FLIP 2005-9C	71	103	23	28	4	773	445	White	Beige	Kabuli
ILWC 292*	72	105	21	16	2	489	320	Violet	Brown	Desi
ILC 482**	66	102	29	28	8	1100	108	White	Beige	Kabuli

* Resistant check, ** Susceptible check

† 1 = most resistant, 9 = highly susceptible. These values are from a plot infested with cyst nematode.

New faba bean breeding lines with resistance to *Orobanche*

The parasitic weed broom-rape (*Orobanche crenata*) is one of the main causes of low and unpredictable yields of faba bean in West Asia and North Africa (WANA), and in the Nile Valley region. Over the last few years, *Orobanche* has destroyed up to 80% of the faba bean crop in WANA countries.

ICARDA has recently developed breeding lines resistant to *Orobanche*. To do this, researchers first developed four hybrid bulk populations by crossing accessions resistant or tolerant to *Orobanche* with high-yielding lines during the 1997/98 growing season. The first hybrid bulk population (HBP/S0/2000) was developed by crossing 16 *Orobanche*-resistant accessions identified by ICARDA with three improved faba lines and varieties: 'Giza 402' from Egypt, and 'Reina Blanca' and 'Aquadolce' from Spain.

The second population (HBP/S0E/2000) was produced by crossing eight accessions with five improved faba bean lines and varieties developed by NARS (ILB 1814 from Syria, 'Giza 4' and 'Rebaya 40' from Egypt, 'Aquadolce' from Spain, and 'Triple White' from Sudan).

The third population (S 98012) was developed from a double (four-way) cross of four parents from ICARDA, two with resistance to *Orobanche* (ILB 4348 and ILB 4392) and two (BPL 1179 and BPL 3011) with resistance to chocolate spot and *Ascochyta* blight.

The fourth population was a back cross (S 98019/2000) of two accessions from ICARDA, one parent with *Orobanche* resistance (ILB 4365) and the other with high yield potential (BPL 2282).

In the 1998/99 growing season, the F_1 crosses and parents of each population were raised in screenhouses. Off-type and diseased plants were discarded. At maturity plants of each population were harvested and the seeds bulked. In the 1999/2000 growing season the bulked seeds of each population of crosses were grown separately, as F_2, in isolated plots, in open field conditions to increase intercrossing within each population through insect pollination. Some of the F_2 seed was used to identify new *Orobanche*-resistant breeding lines.

New faba bean F_8 breeding lines, with resistance to* Orobanche*, developed at ICARDA, compared with the local check (ILB 1814) in the middle, at Tel Hadya, 2005/06.

Table 2.10. Average number and dry weight of *Orobanche* spikes, and number of seeds and seed yield per plant of faba bean F_8 lines at Tel Hadya, Syria, 2005/06.

Group	Population name	*Orobanche*/m²			No. of seeds/ plant	Seed yield (g/plant)
		No. of lines	No. of spikes	Dry weight (g)		
1	HBP/S0D/2000	37	2.7	12.7	25.5	23.0
2	HBP/S0/2000	27	1.9	11.0	27.8	25.6
3	S 98012	3	4.2	21.4	24.9	19.2
4	S 98019	23	4.3	19.5	26.3	22.1
Mean			3.4	16.2	26.1	22.5
Local check (ILB 1814)			53.1	108.9	9.1	10.4

Between 2000 and 2006, segregating populations (F_3 to F_8) of the four groups (HBP/S0D/2000, HBP/S0E/2000, S 98012 and S 98019/2000) were evaluated and their performance compared with a susceptible local check (ILB 1814) under a heavy natural infestation of *Orobanche* at Tel Hadya, Syria, following the pedigree method.

By counting the number of *Orobanche* spikes per plant, researchers were able to estimate the infestation rate. Counting the number of seeds per plant and weighing them gave an estimate of yield. Seed from 90 F_8 lines with the fewest *Orobanche* spikes and highest yield was grown to continue further selection (Table 2.10).

New faba bean with early maturity and high yield

Faba bean (*Vicia faba*) is a major source of protein in many developing countries. It is also used for animal feed and as a break crop in cereal rotation systems to sustain soil fertility. However, various types of stresses cause yield losses estimated at over 50% worldwide. Two of the main abiotic stresses are drought and high temperatures – hence the importance of early maturing varieties that can be harvested before temperatures rise and drought sets in.

ICARDA has recently developed a new faba bean line that matures early. To do this, researchers first chose two improved faba bean accessions. The first was 'Reina Blanca', from Spain, which combines multiple disease resistance – to chocolate spot, rust, and *Alternaria* leaf spot diseases – with high yields and drought tolerance. The second accession was the early-maturing 'Triple White' from Sudan.

Researchers crossed 'Reina Blanca' and 'Triple White' in Egypt during the 1993/94 season and raised the F_1 plants in screenhouses during 1994/95. Segregating generations (F_2 to F_4) were evaluated under natural conditions in the New Valley Research Station in the western desert of Upper Egypt, and compared with the parents ('Reina Blanca' and 'Triple White') and three check cultivars ('Giza 40', 'Giza 674' and 'Giza 429') between 1995 and 1998. The F_5 and F_6 generations were evaluated during the 1998/99 and 1999/2000 growing seasons.

Participants of a traveling workshop discuss performance of a promising faba bean line.

One F_6 breeding line (Line-2/F6/2000) flowered and matured 16 days earlier than the P1 parental genotype ('Triple White'), although its seed yield was not significantly different from that of the three check cultivars ('Giza 40', 'Giza 674' and 'Giza 429') and the P2 parental genotype ('Reina Blanca') (Table 2.11).

Seed of this new early-maturing line is now being multiplied and was released in 2006 to farmers as 'Wadi 1'. The new variety is adapted to the high temperatures in Egypt's western desert and can also be sown as a short-season crop preceding cotton in the intensive agricultural areas of Upper Egypt.

Table 2.11. Performance of an early-maturing faba bean line (L-2/F6/2000) compared with parents (P1 and P2), New Valley Research Station, Egypt, 1999/2000.

Entries	Days to 50% flowering	Days to maturity	100-seed weight (g)	Seed yield	
				g/plant	kg/ha
L-2/F6/2000	34.67	118.00	87.30	68.85	5069
'Reina Blanca' (P1)	64.50	150.83	114.90	76.19	5208
'Triple White' (P2)	32.33	133.50	57.20	54.53	4025
'Giza 40' *	33.83	134.67	67.90	45.44	5394
'Giza 674' *	37.17	138.00	74.50	44.89	5092
'Giza 429' *	35.17	138.50	72.40	45.69	5325
LSD 0.05	0.97	1.20	5.16	6.60	750.01

* check varieties

Effect of storage conditions on detection of plant viruses with tissue blot immunoassay

Tissue blot immunoassay (TBIA) is one of the fastest and cheapest tests for detecting plant viruses. It allows blotted samples to be easily sent from fields to far-away locations for processing.

In 2006, researchers assessed how the duration and temperature of storage or mailing affected TBIA's ability to detect viruses. They cut stems of faba bean infected with *Bean yellow mosaic virus* (BYMV) and *Faba bean necrotic yellows virus* (FBNYV) and blotted them several times on nitrocellulose membrane. The blots were then stored at different temperatures and for different periods of time. A BYMV polyclonal antiserum and an FBNYV monoclonal antibody were used in the test.

Storage of up to nine years at room temperature did not affect the sensitivity of detection of either virus.

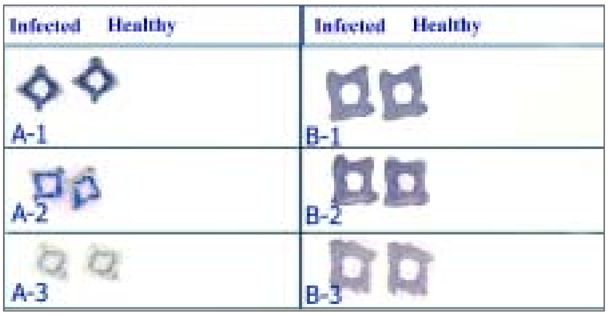


Fig. 2.12. Detection of* Faba bean necrotic yellow virus *(A) and* Bean yellow mosaic virus *(B) using the tissue blot immunoassay in infected faba bean tissues blotted on nitrocellulose membrane and stored at room temperature for 9 years (A-2 and B-2), and at 80°C for 7 days (A-3 and B-3), as compared to the fresh blots (A-1 and B-1).

What is more, both viruses were easily detected when membranes were exposed to 80°C for 10 days, although the reaction intensity fell as exposure time increased.

It was clear that virus particles blotted on the nitrocellulose membrane were stable and withstood poor storage conditions without significant effects on virus detection (Fig. 2.12). This confirms that samples can be prepared close to the field and later processed at suitable facilities.

Integrated management of aphid-transmitted faba bean viruses

ICARDA researchers tested a range of options for reducing the spread of aphid-transmitted faba bean viruses in field experiments in coastal Syria during two growing seasons: 2004/05 and 2005/06. Testing covered a number of management components: planting date, plant density, seed dressing with the insecticide Imidacloprid, the planting of a wheat border crop, and spraying leaves with mineral oil and the insecticide Pirimcarb.

During 2005/06, virus incidence in mid-November plantings was 77% or less (depending on the treatment). This dropped to less than 5% when faba bean was planted later, in early December. Virus incidence decreased by 50-70% when seeds were treated with Imidacloprid (1.4 g of active ingredient per kilogram of seed), compared with no treatment. Virus incidence decreased by 20% with a higher plant density of 33 compared to 22 plants/m^2.

Spraying leaves during the season with only Pirimcarb (0.2 g of active ingredient per liter), or only mineral oil (3%), or both com-

Table 2.12. Virus incidence in early planting (mid-November) and late planting (early December) of faba bean field experiments in coastal Syria in 2005/06.

Wheat border	Plant density (plants/m²)	Seed dressing with Imidacloprid (1.4 g a.i./kg of seeds)†	Virus incidence (%)			
			Foliar spray			
			Mineral oil (3%) 0.2 g a.i./l)	Pirimcarb 0.2 g a.i/l	Pirimcarb + mineral oil	Without spray
Early planting (mid-November) (control)						
Without	22	Non-treated	58.8	55.7	58.4	52.2
		Treated	18.1	21.5	21.9	25.7
	33	Non-treated	55.7	46.3	41.3	39.8
		Treated	14.8	13.3	11.5	12.6
With	22	Non-treated	77.8	62.8	60.0	67.2
		Treated	39.8	30.1	25.8	30.9
	33	Non-treated	56.8	57.3	50.1	51.9
		Treated	30.1	20.4	20.2	23.9
Late planting (early December)						
Without	22	Non-treated	1.5	2.6	0.8	0.6
		Treated	2.5	0.0	1.6	2.5
	33	Non-treated	0.6	0.5	1.7	2.4
		Treated	0.0	1.1	1.0	0.0
With	22	Non-treated	2.5	0.6	1.1	3.2
		Treated	1.6	0.4	1.4	0.6
	33	Non-treated	2.5	0.4	0.0	2.1
		Treated	0.9	2.6	0.6	1.7

† a.i. = active ingredient

Effect of seed dressing with Imidacloprid insecticide on aphid-transmitted faba bean viruses under field conditions as compared to untreated plots (foreground).

bined, did not reduce the spread of persistently aphid-transmitted viruses such as *Faba bean necrotic yellows virus* and Luteoviruses (Table 2.12). However, spraying with either mineral oil or a combination of Pirimcarb and mineral oil reduced the spread of non-persistently aphid-transmitted viruses such as *Bean yellow mosaic virus* and *Broad bean wilt virus*.

The incidence of persistently aphid-transmitted viruses was higher than that of non-persistently aphid-transmitted viruses in both growing seasons. A wheat border did not reduce the spread of persistently transmitted viruses, but did reduce non-persistent spread. In general, the natural incidence of viruses was higher during the second growing season than during the first. Moreover, the virus incidence in experimental plots was similar to the situation in farmers' fields.

Researchers therefore concluded that a combination of late planting, Imidacloprid seed treatment, and a plant density of 33 plants/m² are effective management options to reduce virus disease in faba bean fields in coastal Syria.

Variability in *Ascochyta fabae* and sources of resistance in faba bean in Syria

Ascochyta blight in faba bean, caused by *Ascochyta fabae*, is one of the most important fungal diseases affecting this crop in Syria. The disease is responsible for considerable yield losses.

The recent report in Syria of the perfect or sexual stage of *A. fabae* indicates that this pathogen's population has great potential to evolve. It is necessary to understand variability in local pathogen populations to develop effective resistance in host plants – a key component of integrated disease management. *Ascochyta*-infected faba bean samples were therefore collected across Syria, and 184 fungal samples were isolated and characterized morphologically. Researchers found marked differences in colony color, spore size, growth rate, and sporulation intensity.

The disease-causing abilities (pathogenicities) of representative isolates were then tested in greenhouses on nine faba bean differential lines. Virulence varied significantly among isolates, with an average disease severity of 2.0-6.3 on a scale of 1 to 9. Molecular characterization of the isolates is ongoing.

The resistance of 50 Syrian faba bean landraces was evaluated using an equal mixture of five isolates of the fungus. Only one accession (BPL 2761) was tolerant, with a disease severity of 4. BPL 2761 is therefore potentially valuable for future breeding of resistance to *Ascochyta* blight for Syrian conditions.

Improving yield and nutritional quality of grass pea

Grass pea (*Lathyrus sativus*) is a popular feed and food crop in countries such as Bangladesh, China, Ethiopia, India, Nepal, and Pakistan. It is noted for its resistance to drought, flood, moderate salinity, and its low input requirements. Being a legume, grass pea fixes nitrogen from the air and improves the soil. When other crops fail under adverse climatic conditions, grass pea can be the only crop available for the poor and their livestock. It can be very important during famines.

Although grass pea seeds are tasty and protein-rich, overconsumption can cause a disease of the nervous system known as neurolathyrism: an irreversible paralysis of the lower limbs. The neurotoxin that causes this disease was identified as 3-(-*N*-oxalyl)-L-2,3-diaminopropionic acid (β-ODAP). The level of β-ODAP in dry seeds varies widely, depending on genetic and environmental factors.

ICARDA has a mandate to improve productivity of dryland agriculture and is placing special emphasis on improving yield and quality of grass pea. It has a large germplasm collection of *Lathyrus* species from different parts of the world. Using this precious resource, ICARDA is collaborating with national partners to develop new grass pea lines with improved yield, adaptation, and nutritional quality by reducing β-ODAP to a level safe for human consumption.

ICARDA's grass pea breeding program aims to reduce β-ODAP concentration using three approaches: (1) evaluating germplasm to find material with low levels of the toxin, (2) creating hybrids, and (3) exploiting somaclonal variation (a plant breeding technique that induces variation during *in vitro* cell culture).

Five years of screening showed that no accession from any *Lathyrus* species was free of β-ODAP, although some had low levels. This was species-related. In *L. cicera* seed, for example, the β-ODAP content was relatively low: 0.03–0.22% (0.16% on average). Grass pea seed displayed the greatest range: 0.09–2.4%, while *L. ochrus* accessions had the highest β-ODAP content (0.46–2.5%).

Researchers found four grass pea accessions with a low seed β-ODAP content of less than 0.1%. The level presumed safe for human consumption is less than 0.2%. A very interesting finding was that four accessions of a wild relative of grass pea, *L. ciliolatus* (underground *Lathyrus*), had very low β-ODAP contents: less than 0.05% in dry seeds.

Analysis of a large number of grass pea accessions revealed that samples originating from Bangladesh, Ethiopia, India, Nepal, and Pakistan had high seed β-ODAP contents. Samples from North Africa, Syria, Turkey, and Cyprus had significantly lower seed β-ODAP.

Low-neurotoxin genotypes have undesirable traits, such as late flowering, susceptibility to insects and diseases, and low yields. Researchers therefore started a hybridization program to improve yield, adaptation, and nutritional quality. This was done by transferring the low neurotoxin character to locally adapted germplasm from grass-pea-producing countries, such as Ethiopia. The Ethiopian national program was supplied with a segregating population for testing and selection for low β-ODAP under local conditions. Improved lines were selected in the F_4 and F_5 families with high yields and seed β-ODAP contents of less than 0.08%.

Improved grass pea lines with low β–ODAP levels, being tested at ICARDA.

Recently, the exploitation of somaclonal variation of Ethiopian landraces has produced somaclones that differ in characters like flower color, leaf size, seed color, pod length, and pod shape. This phenotypic variability will be a boon for grass pea breeders in further improving quality and yield. Somaclones with a β-ODAP content of less than 0.09% were also developed. These were tested in different locations in Ethiopia to see whether the β-ODAP content of the ripe seeds varied from place to place.

To avoid out-crossing, improved lines with a high yield potential and low β-ODAP were tested by ICARDA in 2005/06 in isolated areas at Tel Hadya (rainfall 290 mm) and Breda (rainfall 237 mm) in Syria. These lines maintained their high yield and low β-ODAP content under low-rainfall conditions.

In collaboration with national agricultural programs, four grass pea cultivars were recently released: 'Waise' in Ethiopia, 'Ali-Bar' in Kazakhstan, 'Gürb□z' in Turkey, and 'Hassyly' in Turkmenistan. These cultivars could have a great impact on human and livestock nutrition in these resource-poor countries with large semi-arid areas. Since grass pea is an affordable legume for low-income families and a common part of many diets, the release of low β-ODAP cultivars will remove the fear of neurolathyrism in Ethiopia and other countries that produce grass pea. The improvements in quality and yields will increase the welfare of many subsistence farmers in areas where grass pea is grown.

Narbon vetch: a feed legume for low-rainfall areas

Narbon vetch (*Vicia narbonensis)* is one of the most attractive legume species for producing grain and straw as feed in dry areas. Despite the diversity of species available, few have been used as feed crops in dry areas. Currently there are few legume crops suitable for the relatively dry zones with annual rainfall of 200-300 mm, and farmers grow continuous barley. These areas suffer from overgrazing and there is a clear need for legume feed crops, in line with ICARDA's overall objective of developing sustainable farming systems.

Researchers therefore assessed the agronomic potential of improved narbon vetch lines developed at ICARDA during the last 10 years. Trials were conducted at ICARDA's Tel Hadya and Breda sites. These broadly typify the physical conditions of dry areas where farming systems are based on a mix of sheep, goat, and barley production. Nine improved lines were studied over four growing seasons from 2002/03 to 2005/06. Rainfall varied from 492 mm at Tel Hadya in 2002/03, to 237 mm at Breda in 2005/06.

Differences among lines for seedling vigor, winter growth, cold tolerance, and spring growth were small but significant. Improved lines had high seedling vigor, rapid winter growth, and showed good cold tolerance, especially during the severe cold of the 2004/05 season. In addition, narbon vetch showed resistance to bird damage in its early growth stages, and appears to be the most resistant in this respect of all the *Vicia* species tested. The high seedling vigor and early resistance to bird damage are major factors in establishing a good plant stand. Four years' assessment of improved narbon vetch lines showed that they grew well when rainfall was less than 300 mm, at least on heavy alkaline soils. The desirable characters of these promising lines are cold and drought tolerance, wide adaptability, and yield stability.

Differences between environments (i.e. sites and seasons) for grain yield and harvest index were significant. Mean grain yield varied from 0.9 to 1.9 t/ha at Tel Hadya in 2005/06 and 2002/03, respectively. Mean harvest index (grain yield expressed as a percentage of total biomass) varied from 30% at Breda in 2005/06, to 40% at Tel Hadya in the 2003/04 cropping season. Variation among individual lines was also significant, as yields ranged from 0.96 t/ha for line # 2390, to 1.6 t/ha for line # 2239. Grain yield was not always related to total rainfall, as the low rainfall in 2004/05 and 2005/06 at Breda actually produced relatively high grain yields.

Narbon vetch is moderately susceptible to the parasitic weed broomrape (*Orobanche crenata*). Long-season environments favored severe attack by broomrape, eliminating the other advantages of longer seasons on grain yield. The early-maturing lines were also susceptible, but set seeds and formed pods before the worst effects of broomrape were seen. Grain yield was therefore strongly and negatively correlated ($r = -0.75$, $P < 0.01$) with days to flowering. These results indicate the need to search for earlier maturing

This farmer in the Afrin area in Syria gows narbon vetch as an intercrop in his olive orchard – improving soil fertility, benefiting the olive trees as well as the succeeding crop.

types with acceptable yields or more resistance to broomrape.

All lines tested did not perform equally in the test environments. The average grain yields across environments of lines # 2391, 2387, 2380, and 2383 were greater than the grand mean, indicating they had wide adaptability. The harvest index and grain yield are likely to determine the way farmers use feed legumes. Crops like narbon vetch with high grain yield and harvest index can be dual-purpose, being used for grain and straw production. The improved lines with a high harvest index also had a potentially high biomass yield, making narbon vetch a valuable feed legume crop.

Narbon vetch does not lose its leaves following frost, unlike most other feed legumes. Even with rainfall in 2005/06 of 290 and 237 mm, and 42 and 18 nights of frost, it still produced 0.9 and 1.2 t/ha of grain at Tel Hadya and Breda, respectively. It can therefore be a major component of feed when other crops fail. It has upright growth and a high seed retention, which facilitates mechanical harvesting, unlike many other *Vicia* species. Narbon vetch's crude protein content was 26–32% for grain and 8.4–12% for straw. These high values show that narbon vetch has great potential as a supplementary animal feed in dry areas. The vetch is an ideal feed legume for producing winter stocks of straw to feed sheep during the winter peak of feed demand. More research is needed on improving the nutritional value of the grain and straw and lowering anti-nutritional factors.

The attributes of narbon vetch give it huge potential in marginal low-rainfall areas, where other legumes are not suitable. Its adaptability to adverse conditions, large seeds, and high protein content of grain and straw make it a favorite among marginal farmers.

International Crop Information System and International Nurseries Network

ICARDA's International Crop Information System and International Nurseries Network continued to contribute significantly to international germplasm exchange, information dissemination, and availability in 2006. Online tools and resources were published, which are essential for browsing electronic databases on crop variety releases, crop information systems, and international nursery and trial field books.

The International Faba Bean Information System was begun in 2006 and is on track for completion in 2007. This will manage and integrate data from around the world on faba bean genetic resources, to help improve breeding efforts. The faba bean database system follows the model of the International Crop Information System (ICIS), which has been developed by various research centers within the CGIAR, including ICARDA. It will be one of the first systems to implement all three arms of the ICIS, as it includes the geneology management system, data management system, and location information for GIS. The project is supported by the Australian Department of Primary Industries, Victoria.

The CGIAR's Generation Challenge Program supported the development of the Genomic Laboratory Information Management System and the Genomic Management System at ICARDA to integrate genotypic and phenotypic data. These systems were judged the most advanced within the CGIAR in May 2006 and are being tested at CIMMYT, IRRI, the Semiarid Prairie Agricultural Research Centre in Canada, and EMBRAPA in Brazil.

In 2006, ICARDA contacted more than 400 researchers and scientists on the International Nurseries Network contact list to notify them of the nurseries and trials available for 2006/07. There were 106 requests for 1943 cereal and legume nurseries and trial sets. In response, 1679 sets of germplasm samples and special dispatches were sent to about 51 countries. These numbers are consistent with previous years' germplasm sample distribution figures. Field results from our collaborators internationally are expected to be returned to help improve ICARDA's germplasm improvement activities.

Testing seed health

In 2006, the ICARDA Seed Health Laboratory continued to ensure that incoming and outgoing seed was free of pests and pathogens. ICARDA sends out large numbers of 'international nursery' trials to collaborators worldwide.

Large quantities of seed were also sent to research projects to improve rural livelihoods and food security in Balochistan, Pakistan, where there has been severe and prolonged drought, and to Ninevah, Iraq, where long conflict has severely disrupted agriculture. Two tons of barley, spring bread wheat, durum wheat, faba bean, chickpea, vetch, and lathyrus seed was sent to Ninevah, and one ton of spring bread wheat, barley, and cumin seed was sent to Balochistan. Before dispatching these materials, the seed health staff conducted comprehensive tests to ensure they were free of seed-borne pests and pathogens, which covered fungi, bacteria, nematodes, viruses, parasitic weeds, and insects. The seeds were fumigated and treated with appropriate broad-spectrum fungicides.

The Seed Health Laboratory routinely tests 100% of incoming and outgoing seeds for seed-borne pathogens. During 2006 this covered more than 20,000 genotypes.

Outgoing seed

Genotypes for international distribution are tested for the most important pathogens. This involves about 11,000 cereals and 3000 legume genotypes annually. For international nurseries in 2006, about 255 genotypes of faba bean and lentil were tested for seed-borne viruses, such as *Broad bean stain virus*, *Bean yellow mosaic virus*, and *Pea seed-borne mosaic virus*. Testing for *Barley stripe mosaic virus* was also conducted on 2400 barley and wheat genotypes according to the quarantine requirements of the recipients.

Only seed free of pathogens and pests was dispatched. During 2006 there were 272 seed shipments to 62 countries, of which 106 were international nursery requests from 48 countries.

Incoming seed

ICARDA received 22 seed shipments from 13 countries in 2006, and over 5500 cereal and about 1500 legume genotypes were tested for the most important seed-borne pathogens and pests. The most frequently recorded pathogen on wheat was common bunt (*Tilletia caries* and *T. foetida*); infection sometimes reached bunt ball level and required disinfection. Dwarf bunt (*T. controversa*) was also found on one shipment. *Ascochyta* and *Fusarium* species were found on legumes at low rates.

If needed, seeds were treated with fungicide before planting, as only incoming healthy genotypes are planted in post-quarantine fields or greenhouses for further observation.

Inspecting ICARDA's international nursery and seed multiplication fields

The Seed Health Laboratory staff inspected about 200 hectares of cereal and legume crops intended for international distribution or for seed multiplication. Roguing was used to minimize pathogen incidence, when needed.

In barley, the most frequent fungi were loose smut (*Ustilago nuda*) and barley stripe (*Pyrenophora graminea*). A few plots had covered smut *(U. hordei*). Wheat was infected mainly with common bunt (*T. caries* and *T. foetida*) and loose smut (*U. tritici*). In legumes, the main pathogen was *Orobanche* species. However, in faba bean, *Ascochyta fabae* was found most frequently.

Field inspection of post-quarantine fields showed the most common cereal infections were common bunt and the loose smuts.

Mega-Project 3

Improved Land Management to Combat Desertification

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 house around 2.1 billion people. More importantly, 72% of drylands are in developing countries and approximately half of the worlds' poor live in drylands. Even by conservative estimates of land already degraded, desertification affects more people than any other environmental problem.

Earlier definitions failed to emphasize that desertification is a development problem and not specifically an environmental one. This is now clearly recognized by the United Nations Convention to Combat Desertification (UNCCD). For example, the convention states that "national action programs, designed to combat desertification, must be fully integrated into other national policies for sustainable development"… "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 including 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. Technology, institutional and policy options are required to prevent further land degradation and build viable livelihoods.

'Improved Land Management to Combat Desertification and Increase Productivity in Dry Areas' (Mega-Project 3) aims to identify options for rehabilitating degraded land resources and simultaneously strengthening land management systems to control degradation and sustain future production in order to contribute to sustainable livelihoods. Major elements of the Project include: 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 managing land, water and watersheds (linking to MP1), vegetation (linking to MP2) and rangelands; policy and institutional research (linking to MP5) to create an enabling environment for combating desertification; and institutional strengthening and capacity building in integrated approaches to sustainable land management.

Tribal dominance: implications for rangeland management in Morocco

Overgrazing and the spread of cultivation are two of the major causes of degradation of the rangelands of northeast Morocco. The creation of pastoral cooperatives in 1988 aimed to improve the use of rangelands. However, these cooperatives focused on improving services to pastoralists rather than on measures to prevent degradation. Previous experiences in pastoral management and pastoral organizations show that customary access rights to rangelands are essential for successful collective management. In Morocco, the creation of the pastoral cooperatives took this into account and cooperatives reflect local ethno-lineage systems. This means that members of cooperatives all belong to the same social unit – tribe, *fraction* (sub-tribe), or *douar*.

To get a better understanding of how different groups use the rangelands, researchers from ICARDA, the Institut National de Recherche Agronomique (INRA), Oujda, and the Centre de Cooperation Internationale en Recherche Agronomique pour le Développement (CIRAD) studied the area traditionally controlled

Community structure and dynamics are important factors in the management of rangelands in north-eastern Morocco.

by the Northern Beni Guil tribe, the present-day rural communes of Tendrara and Maatarka. Nine pastoral cooperatives correspond with the nine major *fractions* of the tribe, but herders of all *fractions* are still using the whole Beni Guil territory because the territorial boundaries are not clear. While this ensures that livestock can graze the rangelands freely, it also means that the interests of different *fractions* conflict and that it is difficult to manage the rangelands collectively.

First, the research team mapped and characterized the Beni Guil rangelands. Rapid assessment by herders showed that half the rangelands were severely degraded. As expected, stocking rates were higher on better, non-degraded rangelands, particularly in winter and spring when there was more forage on the non-degraded rangelands than on the degraded rangelands. At these times livestock graze the best rangelands, so the stocking rate on these rangelands is higher.

Table 3.1. Ranking of nine *fractions* (F) of the Beni Guil tribe, Morocco, according to their dominance of rangeland.

	Population† (residents)	Assets† (livestock) (%)	Rangeland use† Cultivated area (%)	Rangeland use† Stocking rate (%)	Rangeland characteristic Degraded (%)	Rangeland characteristic Appropriated (%)	Dominance index‡ domL	Dominance index‡ domC
F2	5.8	8.0	9.3	18.1	43	13	1.00	0.87
Dominant/rangelands								
F8	18.9	28.7	12.2	15.7	45	19	0.96	0.00
F3	11.2	17.9	11.2	10.2	53	18	0.82	0.08
Dominant/cultivation								
F1	6.5	4.6	12.1	9.0	76	3	0.09	1.00
Dominant/relative								
F6	7.9	9.2	13.2	11.7	73	8	0.26	0.68
F4	7.2	6.5	22.4	9.5	61	15	0.46	0.73
Dominated/relative								
F7	10.5	6.5	6.3	6.2	66	13	0.30	0.11
Dominated/absolute								
F5	24.9	13.9	10.5	11.1	87	12	0.00	0.07
F9	7.1	4.7	2.8	8.4	82	14	0.02	0.03
Total	100.0	100.0	100.0	100.0				

†Distribution of variable according to the nine *fractions* (% of total)
‡Normalized value of the principal component factors in the principal components analysis
domL: dominance through greater livestock numbers; domC: dominance through cultivation of large areas

Table 3.2. Factor analysis of dominance of rangeland use for the Beni Guil tribe, Morocco.

	domL	domC
Indicators of dominance		
Livestock/population	0.378	0.024
Cultivated area/population	-0.008	0.469
Stocking rate/population	0.156	0.43
Indicators/rangeland characteristics		
Appropriated rangelands (%)	0.296	-0.432
Degraded rangelands (%)	-0.41	0.002

domL: dominance through greater livestock numbers
domC: dominance through cultivation of large areas

The survey results showed that half the map's polygons were used by a single *fraction*. These '*fraction*-appropriated rangelands' are significantly less degraded than the rangelands that are used by more than one *fraction*. There are two reasons for this. First, the '*fraction*-appropriated rangelands' are less cultivated than the other rangelands. Secondly, the stocking rates are not only lower but are also stable throughout the year. The characteristics of these '*fraction*-appropriated rangelands' suggest that they are, in fact, governed by informal rules, even though they are 'officially' open to all.

Next, the research team analyzed how each of the nine *fractions* used the rangelands. The populations, livestock, cultivated area and stocking rate on the rangeland for each *fraction*, were compared as well as the average characteristics of the rangelands used by each *fraction*. For example, Table 3.1 shows that, although *fraction* 2 (F2) makes up only 6% of the total Beni Guil population, they own 8% of the total livestock, cultivate 9% of the total cultivated area and their livestock represents 18% of the stocking rate on the rangelands. In addition, only 43% of the rangelands used by F2 are degraded and 13% are used (appropriated) by F2 alone.

In order to make quantitative comparisons between the *fractions*, researchers aggregated the indicators in a principal components analysis. The analysis (Table 3.1) suggests that there are two types of dominance in rangeland use. In the first (domL), *fractions* own a greater share of the livestock population, select the best rangelands, and are able to exclude other *fractions*. In the second (domC), the *fractions* cultivate extensive areas to secure access to surrounding pastures. Normalized indexes provide the ranking of the *fractions* according to their level of dominance (Table 3.2) and show that F2 dominates the rangelands in all aspects, while other *fractions* only dominate in specific areas, such as overgrazing (F8 and F3) or cultivation (F1). At the bottom of the ranking, there are two *fractions* (F5 and F9) that are completely dominated in all aspects.

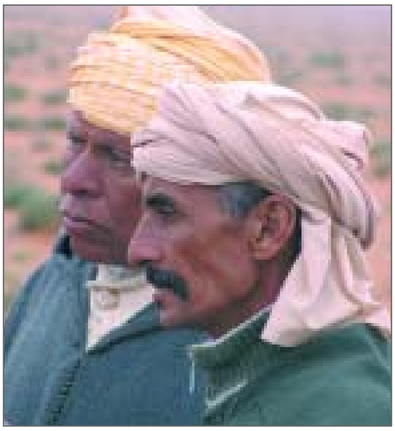
Understanding the origins of the bargaining power of the different *fractions* will be necessary to improve the collective management of these rangelands. So, the research team then considered the pattern of dominance. To understand this really needs a sociological study but the team's discussions with the leaders of the nine *fractions* did give some preliminary indications of the origins of power. Grazing dominance (domL) seems to be associated with historical power struggles between *fractions* and can be justifiably called domination, whereas cultivation dominance (domC) happens by default, and is used by the weakest groups to ensure access to the rangelands.

Finally, the research team did a regression analysis of the impact of *fraction* dominance on production and livelihood strategies – such as feeding costs, fattening activities, giving up breeding livestock, seeking work off-farm, and migrating. This took into account the composition and assets of households.

Overall, the level of dominance in cultivation (domC) had no impact on individual strategies. Herders who belong to *fractions* that dominate the area by appropriating the best rangelands (domL) are the least vulnerable as they are less likely to quit breeding livestock and migrate. These herders also have the lowest feeding costs and obtain the best price for their lambs. This means that grazing dominance is beneficial for *fraction* members, whereas cultivation dominance makes no difference. This might suggest that promoting initiatives to limit further cultivation of the rangelands would be easy as this would have no impact on members of the *fractions* with weakest cultivation dominance.

So, what are the prospects for pastoral cooperatives? Technological innovations have failed to combat rangeland degradation. Most researchers, development actors and some policy makers now recognize the role of formal and informal institutions. Recent approaches promote a combination of community participation and decentralized management of natural resources for managing forests, watersheds, and rangelands. But the implications of these approaches for tribes living in Maghreb rangelands have not yet been fully addressed. For example, for the success of community-based natural resource management, the resource and its users must first be clearly delineated. But the need for clear boundaries conflicts with the need to keep a certain degree of fuzziness in rangeland boundaries to allow livestock to graze freely.

Following the creation of the pastoral cooperatives, *fractions* in rural communes in Tendrara and Maatarka, Morocco, now officially manage rangelands. However, in reality, tribal *fractions* compete for access to grazing that has traditionally been open to all. And in this competition, all *fractions* are not equal. In the powerful *fractions* that dominate by selecting and appropriating the best rangelands, herders are better off. This means that the objectives of good natural resource management and equitable access to resources are difficult to achieve simultaneously. Even though certain *fractions* in effect prevent degradation of some rangelands by appropriating them for their use, by doing this they disadvantage the pastoralists of other *fractions*.



Project studies are helping to understand social dynamics and their influence on technology adoption in rangelands.

This suggests that, to be equitable *and* effective, rangeland management in Tendrara and Maatarka has to be organized at the tribe level. The recently created union of pastoral cooperatives offers a formal and functional framework for addressing conflicts and starting negotiations.

A new consortium to combat land degradation

A new consortium brings together the research expertise of 11 CGIAR research centers to tackle land degradation. Called the Oasis Consortium, it is co-convened by ICARDA and ICRISAT. The Consortium brings together a broad, multidisciplinary range of capacity, expertise, partnerships, and geographic experience in dryland degradation and builds on the work of its predecessor, the Desertification, Drought, Poverty and Agriculture (DDPA) consortium.

Why Oasis is needed

The drylands are home to one-third of humanity and some of the least developed nations. The poorest people in the drylands are farmers and pastoralists. They struggle valiantly and with great ingenuity to eke out a living from fragile environments that are particularly vulnerable to degradation.

Improved Land Management to Combat Desertification

The CGIAR Centers have invested significant effort in research in sustainable dryland development. But these efforts are fragmented and poorly coordinated.

An eight-year plan with five goals

Scientists can help solve intractable problems only by coordinating their efforts. The Oasis Consortium aims to do just this to tackle desertification. It is a partnership between people working on the ground and scientists in advanced research institutions from many disciplines. Already, the Consortium has consulted widely to set five goals, which are expected to make a significant impact.

The first goal is to develop an effective way of assessing and measuring dryland degradation at appropriate scales. This means taking into account subtle, long-term changes in the state of natural resources. It is a complex task. And, in addition, economists need to assess the cost of ecosystem goods and services, taking into account the needs of land users – especially the poor – and the needs of national, regional and global communities. Tackling this will produce much more effective tools for development agencies and developing countries to assess land degradation, particularly in sub-Saharan Africa.

The second goal is to find a way of measuring the processes that cause soil and water erosion, flush away nutrients, and diminish biodiversity – and then to devise ways to prevent these happening. This effort is expected to produce practical, proven ways to use and recycle nutrients and water, preserve dryland agrobiodiversity, and to supplement nutrients and biodiversity by bringing them in from external sources. These tools will be used on farms throughout Africa and Asia.

The third goal is to find ways to change the policies, market forces, and institutional arrangements that aggravate land degradation. This effort will pay off in key policy changes and better dryland management.

The fourth goal is to find out what motivates dryland users to do things that degrade land. This would help to find ways to change their perceptions so that they become motivated to act in ways that lead to more sustainable, diverse, remunerative, and resilient dryland management. Here, the Consortium expects that there will be a shift from low-value to higher-value farming, such as combining tree-crops and livestock, and growing high-value crops and processing livestock products that capitalize on the particular advantages of dryland environments.

Lastly, there is a great deal of knowledge about how to manage land successfully to prevent degradation. The problem is how to share this knowledge with disadvantaged, isolated rural communities. The Consortium's efforts towards this are expected to produce new models for scaling-up better natural resource management.

Partnerships

The Oasis Consortium will build on strong existing partnerships with all the major stakeholders in desertification, such as UNCCD, TerrAfrica, United Nations agencies (UNEP, UNDP, UNESCO), the Sahara and Sahel Observatory, regional NARS bodies, NGOs, and funding agencies such as GEF, IFAD, and USAID. The Consortium will also make the most of other programs with parallel aims that the CGIAR Centers are involved in. These include the Desert Margins Program (ICRISAT, sub-Saharan Africa), the Mashreq and Maghreb project (ICARDA, North Africa and West Asia), and the CACILM project (ICARDA, Central Asia and the Caucasus).

Mega-Project 4

Diversification and Sustainable Improvement of 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, with crops and livestock both contributing 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 current agricultural production systems; increasing and diversifying outputs; improving the safety, quality and marketability of 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.

Greenhouses increase farmers' incomes in Yemen and Afghanistan

Increased income from high-quality cucumber crops in Yemen

Farmers in Yemen's rainfed terraces produce many food crops, but their returns are low. This has contributed to a rural exodus – particularly by men seeking other employment – and a decline in the maintenance and productivity of terraced lands. Attempts to encourage farmers to remain on the land have been successful only where irrigation water is available and cultivation of cash crops is possible.

A two-year project funded by the French-Yemen food aid program aims to introduce and promote affordable, sustainable systems of protected agriculture that use water efficiently to produce high-value crops in Yemen's mountain terraces. It involves installing simple greenhouse structures at 35 pilot sites.

Greenhouse production of cash crops is helping to increase farm incomes in Yemen.

By increasing water-use efficiency and therefore farmers' incomes, the project is helping to maintain terraced lands and conserve natural resources. This supports the Government of Yemen's rural development and food security policies.

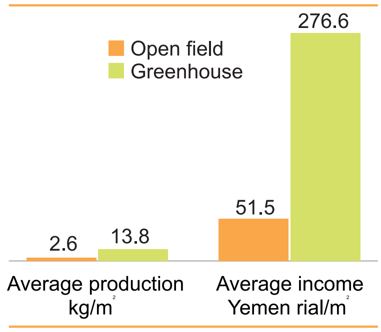


Fig. 4.1. Average cucumber yields and income per square meter in open fields versus greenhouses in Yemen, 2005. US$ 1 = YER 197 (approx)

Simple greenhouses have already been installed at 17 pilot sites and ICARDA has provided technical support for the participating farmers. Project staff carefully studied the farmers' socioeconomic profiles before installing the greenhouses, and production records were collected on a routine basis.

Training is a key component of this project. Using the train-the-trainer approach, ICARDA staff and consultants have improved knowledge among extension agents, agricultural engineers, and technicians. The project gave farmers on-the-job training and developed five handouts in Arabic on protected agriculture.

The first year yielded very promising results. Farmers using greenhouses to grow cucumber generated good income while increasing water and nutrient use efficiency and yields per unit of land (Fig. 4.1).

Producing high-quality cash crops in Afghanistan

To speed up rural development in Afghanistan, ICARDA developed a three-year project for transferring intensive cash-crop production systems to farmers. The project, which began in January 2004 and ended in March 2006, was supported by USAID.

The participants – 35 farmers in six provinces – increased their incomes by as much as 135% using the protected agriculture system to produce high-quality cash crops. Seeing the success of their neighbors, many more farmers have requested training from ICARDA in the greenhouse technology. In April 2006, 30 farmers in Kunduz agreed to pay 50% of the cost of the greenhouses in exchange for technical support from ICARDA and an on-the-job training course (21-27 April 2006).

An economic analysis showed that, compared with open-field production, cucumber production in greenhouses yields four times the outputs and five times the net income per unit of land. Equally important, it provides nine times the net return per unit of water.

By developing local capacity in protected agriculture techniques, the project sought to ensure that its outcomes were sustainable. By March 2006, 364 people had received training in Afghanistan. A series of eight training manuals were also published in the local language, covering greenhouse installation, climate control, drip irrigation, crop nutrient and management needs and vegetable production methods.

In 2005, a Protected Agriculture Center (PAC) was established in Kabul to conduct research and provide training, technical support and advisory services. Demonstration greenhouses at the center have helped to generate farmer interest and

Dr Ahmed Moustafa (left), Coordinator of ICARDA's Arabian Peninsula Regional Program, demonstrates protected agriculture technologies to Afghan farmers.

promote adoption. The first harvest – 1.7 tons of cucumber from one greenhouse – was produced in only 75 days, generating returns of U$1200.

A workshop at PAC on greenhouse manufacturing techniques helped to reduce greenhouse costs by 40% by promoting the use of locally available materials. Fifteen Afghan technicians received training at this workshop, supporting the sustainability of the project.
The project also organized six other workshops and seven farmer field schools. The final workshop, held on 19 March 2006, brought together 65 national and international experts, 17 farmers, and representatives of the Afghan government, the FAO, Kabul University, the French embassy, and many international development and agricultural research agencies. The participants requested support from ICARDA to continue the project and expand it to other provinces, and to support the formation of a protected agriculture growers' association in Afghanistan.

The greenhouse technology has had significant impact on growers' incomes, while enabling farners to use marginal land, and reduce labor and water requirements. This provides substantial evidence that the technology is economically viable in the context of Afghan agriculture. This is very important in light of the need to find suitable livelihood alternatives for poppy growers. While Afghanistan's ban on poppy cultivation is a positive development, it has serious implications for the rural economy. Poppy farmers and people who harvest poppy – a highly labor-intensive process – have lost a major source of income. According to interviews with farmers in poppy-growing areas, the net profits from greenhouse production of high-quality cash crops can easily replace – and surpass – the profits from poppy cultivation (Fig. 4.2).

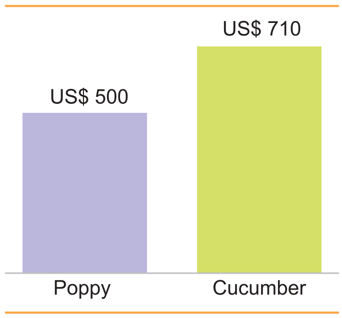


Fig. 4.2. Comparison of net income from poppy and greenhouse cucumber in Afghanistan, over one year of production. Figures are based on one jerib of poppy (2000 m^2) and one greenhouse (270 m^2) of cucumber, and were derived from interviews with farmers and a socio-economic study.

Effect of lower cost feed on the quality of meat from Awassi lambs

The high cost of feed reduces profits for small farmers fattening lambs in intensive production systems in Syria. Less expensive feeds of equal or better quality can boost farmers' incomes.

ICARDA researchers compared the effects of cheaper feeds (least-cost diets) and traditional costly feeds on meat quality. They conducted two fattening trials in 2003/04. In the first, on-station trial, they fed lambs two least-cost diets and a control diet of traditional feed. In the second, community-based participatory trial, they tested the most promising least-cost diet on three fattening farms in the Khanasser valley, northern Syria.

Weaned male Awassi lambs were used for both on-station and on-farm fattening trials. In the on-station trial, two least-cost diets and one traditional diet were fed to lambs for 90 days. In the on-farm trial, lambs were fed the best least-cost diet (as determined by the on-station trial) for 72 days and compared with lambs fed the traditional diet (Table 4.1). The least-cost diets included molasses and wheat straw treated with urea. These ingredients are available locally and are cheaper than traditional ingredients, but farmers are unfamiliar with them.

The fasting lambs (kept without feed, but given water) were slaughtered at the slaughterhouse in Aleppo, the carcasses kept at 2°C for 35 hours, and the *Longissimus dorsi* muscles extracted.

Table 4.1. Ingredients of diets in on-station and on-farm fattening trials.

Ingredients	On-station trial				On-station trial		
	Control	Diet 1	Diet 2	LCD	Control Farm 1	Control Farm 2	Control Farm 3
Broken corn	■		■	■			
Broken faba beans		■					
Cotton seed cake	■	■	■	■		■	■
Whole barley grain	■	■	■	■	■	■	■
Wheat bran	■	■	■	■	■	■	■
Wheat grain					■	■	■
Minerals, vitamins and salt	■	■	■	■			
Molasses			■	■			
Vetch grazing					■		
Barley/wheat straw	ad lib				ad lib	ad lib	ad lib
Urea treated wheat straw		ad lib	ad lib	ad lib			

Awassi ram lambs in the on-farm fattening trial in Khanasser Valley, northern Syria.

The pH of the meat was recorded at slaughter, and at 35 hours and 72 hours after slaughtering. One *Longissimus dorsi* muscle from each lamb was immediately stored at –20°C; the other was stored for 72 hours at 2°C after slaughtering, and then at –20°C until evaluation.

The pH of meat samples from on-station (average 5.99) and on-farm trials (average 6.05) did not differ significantly. Changes in the pH of meat samples from both trials were normal, and fell as the meat aged and the sugars were converted. In on-station trials, the pH was 6.17, 5.97, and 5.84, at 0, 35, and 72 hours, respectively, after slaughtering ($p<0.0001$) and in on-farm trials, 6.6, 5.8, and 5.76 ($p<0.0001$).

The meat was cooked for 70 minutes in a circulating water bath at 70°C core temperature of meat, then cut into small cubes, and evaluated by a panel of 27 men and women. They ranked the meat for tenderness, juiciness, taste, and smell on a scale of 1 (low) to 6 (high).

The panel detected no difference in smell, taste, and juiciness between the meat from lambs fed the two least-cost diets and the control diet in on-station trials. The panel rated the tenderness of meat from lambs fed least-cost diet 2 and the control diet the same. However, they rated meat from lambs fed least-cost diet 1 more tender than meat from lambs fed the control diet ($p=0.032$) (Fig. 4.3).

The evaluation of the meat from lambs in the on-farm trials produced very similar results to that from lambs in the on-station trials. The panel detected no difference in smell and taste between the meat from lambs fed the least-cost diet and the meat from lambs fed the control diet ($p>0.426$). Similarly, there was no difference in juiciness and tenderness between animals fed different diets on farms 1 and 2 ($p>0.381$). However, on farm 3, the meat from lambs fed the control diet was considered



Left to right: Evaluating the lamb carcasses; preparation; and evaluation of meat samples

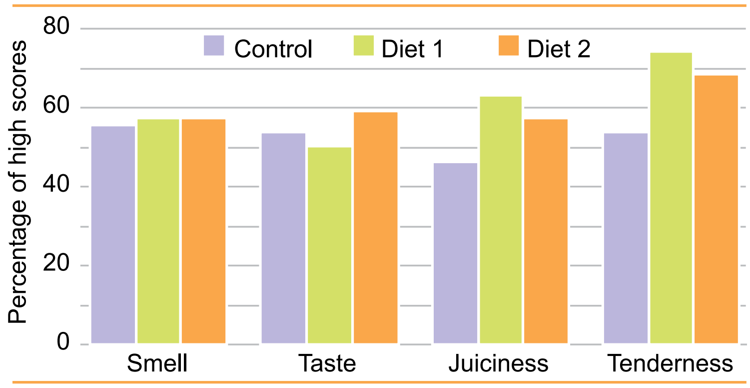


Fig. 4.3. Percentage of high scores (4 to 6) for meat quality of lambs fed two least-cost diets and a control diet in on-station trials. Control = traditional diet; diet 1 and diet 2 = least-cost diets.

more juicy and tender than meat from lambs fed the least-cost diet ($p<0.003$).

Researchers also measured the increase in weight of lambs fed different diets. Lambs fed the least-cost diets gained weight at the same rate or faster than those fed the traditional diets. The low-cost diets did not affect the aging or taste of the meat. This means farmers need not be concerned that least-cost feed will lower the quality of meat. By using lower-cost feeds they will raise their profits.

Farmers were enthusiastic about the low-cost feeds, in particular with the use of molasses. However, at present there is no system to deliver molasses to farmers, although it is readily available. ICARDA has encouraged farmers, the feed industry, and the government to look at ways to remove this constraint.

Simple changes to yogurt-making add value in northern Syria

Yogurt is widely consumed in West Asia, either by itself or in local dishes. In Syria, resource-poor farmers produce most of the yogurt. For example, sheep farmers in the El-Bab area of northern Syria derive 48% of their income from milk and yogurt.

To improve milk processing and yogurt production, ICARDA researchers used a participatory approach to test simple new technologies in two communities, Abu-Jabar and Bugaz, in El-Bab, Syria. Farmers here produce yogurt and cheese from flocks averaging 49 milking ewes in semi-intensive crop-livestock production systems.

Participatory workshops in both communities to identify problems in yogurt production involved both male and female farmers. Women were invited because it is the women who collect milk and process dairy products. A series of training workshops was then held for farmers on the basics of hygienic milk production and improving yogurt processing.

The traditional way of making yogurt is very prone to contamination. Farmers reported that the yogurt was often sour, had a poor texture, crumbled, and had a yeast flavor. All these lowered the quality and market value of the yogurt. Another problem was that the yogurt was not firm and collapsed when transported.

To overcome the problem of yogurt collapsing on the trip from farm to market, farmers tested three starters that produce firm yogurt and compared them with the starter they normally use. One of the new starters produces yogurt with a very mild flavor and high viscosity, the second, a yogurt with a mild flavor and medium viscosity, and the third, a yogurt with a strong flavor and medium-to-low viscosity.

Farmers identify problems in making yogurt and choose methods of improving processing at a participatory workshop.

Yogurt made by traditional methods and transported over bumpy roads loses its firm texture.

The viscosity of the three types of yogurt was measured using a viscometer after mechanically shaking the yogurt for 15 minutes. Firmness was measured with a texture analyzer, using a 20-mm cylinder probe to penetrate 25 mm into the yogurt. Farmers then evaluated the yogurts and tested market reactions.

The new starters increased viscosity by 60-72% compared to yogurt made with traditional starters. The new starters also produced yogurt that was 20-30% firmer and could be transported without collapsing.

Adults preferred the strongly flavored yogurt made with the traditional starter. However, children preferred the mild and very mild yogurt produced with the new starters. The crucial test was how the yogurt sold in the market. Farmers' net incomes increased by 18% from yogurt made with the new starters. Strongly flavored, medium-to-low viscosity yogurt fetched the highest market price (30 Syrian pounds (SYP)/kg), followed by mild flavored medium viscosity yogurt (27 SYP/kg), and the traditional yogurt (25 SYP/kg). Yogurt with a very mild flavor and high viscosity fetched the lowest price (22 SYP/kg). Farmers could cover the cost of transporting yogurt to market (5 SYP per 2.5-kg bucket) by changing from the traditional starter to the starter that makes strongly flavored medium-low viscosity yogurt (Fig. 4.4).

Farmers opted to make yogurt with the new starters that produced a firm product and increased their income by 18%. The participatory approach and market evaluation were key to finding a solution and testing the new technology.

Farmers and their families test yogurt types made with a traditional starter and new starters.

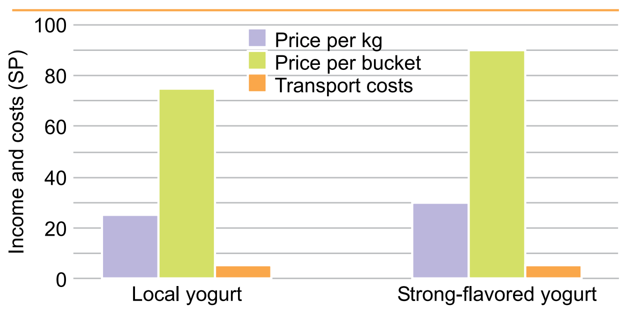


Fig. 4.4. Income and transport costs for local and strong flavored yogurt. A bucket contains 2.5 kg of yogurt (US$ 1 = SYP 50.5).

Zero-till direct sowing improves returns in cereal-legume rotations

Dryland farming systems in CWANA are becoming more intensive, which is threatening the region's soils and water supplies. However, zero-till systems have been developed that reduce soil erosion, boost soil fertility, and improve the water-holding capacity of soil. Likewise, conservation tillage practices aim to retain plant residues from previous crops for the same reasons. These systems can also give farmers higher yields and higher returns.

ICARDA researchers investigated zero-till and conservation tillage systems and compared them with conventional tillage systems in wheat-legume rotations. They conducted trials for five years on different systems: (1) conservation tillage with shallow tillage for wheat and deep tillage for lentil; (2) conventional tillage (deep for both wheat and lentil); (3) conservation tillage with shallow tillage for both wheat and lentil; (4) zero-till direct sowing leaving plant residues; and (5) zero-till direct sowing with plant residues removed.

Table 4.2 shows the average grain and straw yields for wheat and lentil for the five tillage systems over the five years 2002-2006. Conservation shallow tillage for wheat after lentil and deep tillage for lentil after wheat ('conservation shallow-deep' in Table 4.2) gave the highest wheat grain yields in most years, when compared to conventional tillage. This system also gave the highest mean straw yields for wheat.

Wheat also did well in the zero-till direct sowing system with the plant residue left, especially in the driest season (2005/06). In dry years the plant residue prevents moisture loss from the soil, but in wetter years it creates problems for the direct sowing drill machines.

Mean lentil straw yields were significantly higher under zero-till direct sowing. This was particularly the case under zero-till direct sowing with residue in the driest season (2005/06). There was very little difference in lentil grain yield between conservation and conventional tillage systems and zero-till direct sowing (Table 4.2).

These results show that in cereal-legume rotations in dryland farming systems, yields are higher for conservation tillage (when shallow tillage is used for the rotation's cereal crop and deep tillage is used for the legume crop) than for conventional systems (where deep tillage is used for both cereal and legume crops in the rotation). In fact, most farmers in Mediterranean lowlands are already using this 'shallow-deep' conservation tillage system in cereal-legume rotations.

Long-term field experiments have provided valuable information on zero-till systems, helping to devise practical recommendations for farmers.

Table 4.2. Average grain yield of wheat and lentil in two conservation tillage, one conventional tillage, and two zero-till direct sowing tillage systems, Tel Hadya research station, Syria. The means are for the five-year period 2002-2006, for wheat-legume rotations.

Tillage system	Mean crop yield (t/ha)			
	Wheat		Lentil	
	Grain	Straw	Grain	Straw
1. Conservation (shallow-deep) tillage	3.96	6.73	1.15	1.48
2. Conventional (deep-deep) tillage	3.85	6.05	1.14	1.69
3. Conservation (shallow-shallow) tillage	3.58	5.61	1.10	1.48
4. Zero-till direct sowing (residue left)	3.29	5.13	1.07	1.81
5. Zero-till direct sowing (residue removed)	3.33	5.83	1.12	1.83
Standard error†	0.09	0.21	0.05	0.06

† Differences between tillage systems were significant for wheat grain yield, wheat straw yield and lentil straw yield at $p<0.01$, but were not significant for lentil grain yield

Zero-till direct sowing, however, may give farmers higher returns, particularly when residues are removed (Table 4.3). Lentil net returns were higher under zero-till direct sowing, with or without residues, than under conservation or conventional systems. Wheat net returns were also higher under zero-till direct sowing with the residue removed. So, zero-till direct sowing with the residue removed gave farmers the highest net returns. But whether or not farmers can use this system depends on whether zero-till drill equipment is available in their area for them to use.

In very dry seasons, for example the 2005/06 season, yields from zero-till direct sowing can be much better than from conventional tillage systems. During these particular trials, zero-till plots were sown at the same time as the other tillage-treatment plots, so as not to introduce another factor (sowing date) into the trial. Normally, sowing would be earlier in zero-till than in conventional tillage systems because seed is drilled directly and there is no need to prepare the land first. This means that the plants emerge early, covering the soil and reducing evaporation losses.

In the dry season of 2005/06, when rainfall from October to December was less than half the rainfall in the other years, the plants grown in the zero-till system did well even though they were sown at the same time as plants in the other systems. The plants grown in the conservation and conventional systems, however, did not do well. This means that sowing crops early with zero-tillage is likely to give higher yields. For every day gained by early planting with zero-tillage, yields are likely to increase by 20 kg/ha compared with conventional tillage.

The value of sowing early with zero-tillage was confirmed by zero-till direct sowing trials with chickpea and wheat at ICARDA's Tel Hadya research station in 2005/06. Chickpea yielded 78% more grain, and wheat 44% more grain, compared to conventional tillage systems. These directly-sown zero-till crops took advantage of the moisture available in the soil from winter rains in their early growth stages and developed deep root systems. Then, during the dry period later in the cropping season, they drew moisture

Table 4.3. Input costs and net returns (Syrian Pounds/ha) under two conservation, one conventional, and two zero-till direct-sowing tillage systems, at Tel Hadya research station. The means are for the five-year period 2002-2006.

	Wheat			Lentil			Wheat-lentil rotation
	Input cost	Income	Net return	Input cost	Income	Net return	Net return
1. Conservation (shallow-deep) tillage	12,205	44,573	32,368	15,569	22,308	6,739	19,554
2. Conventional (deep-deep) tillage	13,378	43,324	29,946	15,566	23,273	7,707	18,827
3. Conservation (shallow-shallow) tillage	13,065	40,253	27,188	14,240	21,676	7,436	17,312
4. Zero-till direct sowing (residue left)	11,430	36,968	25,538	14,226	23,004	8,778	17,158
5. Zero-till direct sowing (residue removed)	11,479	41,826	30,347	14,255	23,764	9,509	19,928

1US$ = 50.5 Syrian pounds

Direct-drilling equipment from India, originally designed for rice, is being adapted for use in wheat and intercropping systems.

from deep in the soil profile. When farmers do not have the equipment for zero-till direct sowing, then the next best option is to shallow till when planting cereals after legumes and deep till when planting legumes after cereals. Deep tillage after wheat turns the plant residues into the soil and makes sowing legume seed more successful. Yields are not as high with local implements for zero-till, such as 'ducks-foot' and local drills, as with modern machinery. Ideally, zero-till direct sowing drills should be manufactured by local workshops.

As well as saving time and fuel, zero-tillage improves soil structure, makes effective use of soil moisture, and gives higher yields, particularly in dry years. Zero-till also preserves precious topsoil. Studies show that for each ton of wheat produced under conventional tillage systems, 12 tons of topsoil is lost compared with about 0.5 tons under zero-till systems. In addition, zero-till gives farmers in dryland farming systems higher returns from cereal-legume rotations.

Mega-Project 5

Poverty and Livelihood Analysis and Impact Assessment in Dry Areas

Introduction

Poverty, in its broadest sense (income poverty, water poverty, 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 its environment, including patterns of adoption and impacts of improved technologies. 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 research program development, testing and verification, in order to maximize relevance and adoption of new options and pathways by individuals, communities and institutions. 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.

Improving food security and alleviating poverty in arid agriculture, Balochistan

Sustainable market-oriented agricultural production can improve the livelihoods and food security of rural people in Balochistan province, Pakistan. To develop appropriate farming practices for this arid area, ICARDA is working to test new technologies with national research organizations, such as the Arid Zone Research Center (AZRC), Agricultural Research Institute (ARI), Technology Transfer Institute (TTI), and the National Agriculture Research Center (NARC).

In the districts of Mastung, Qilla Saifullah, and Loralai, researchers are focusing on improving the management of scarce water resources, improving range management and livestock productivity, improving crop productivity, and introducing agro-processing.

H.E. Oweis Ghani (second left), Governor of Balochistan, visiting demonstrations of protected agriculture at the Agricultural Research Institute, Quetta.

In 2006, protected agriculture, using greenhouses, was shown to optimize the use of scarce water resources. Farmers tested cucumber in three protected plots for one season, and the harvest fetched good prices. The net farm income was estimated to be US$99.20, while the income per cubic meter of water used was US$2.88.

Researchers also found that introducing improved wheat, barley and lentil varieties that are tolerant to drought and cold, and high-value crops such as olive, almond, pistachio and pomegranate, improved farm productivity.

One high-yielding, cold- and drought-tolerant wheat variety was sown in demonstration plots on farmers' fields, and five varieties were tested on-station. A wheat variety developed between 1985 and 1995 was also tested. One barley variety from ICARDA and two barley varieties developed earlier were distributed to farmers. Three lentil varieties from ICARDA and one developed earlier were distributed to farmers for demonstration plots. Varieties that proved successful in on-farm trials are now being distributed through community-based seed enterprises. Three mobile seed-cleaning machines shipped from Syria to Akhtarzai, Duki, and Dasht mean that high-quality seed can be produced. Farmers have been trained to operate, maintain, and manage the machines.

Field day in Dasht, Mastung District, Balochistan, 14 May 2006.

Women and two trainers in Siddiqabad, Nali Wali Zai, and Dasht were taught better methods of drying surplus vegetables, so they do not have to buy costly fresh vegetables during the winter season when produce is scarce.

Women in Dasht were also taught how to make apple jam, which was especially liked by children. The returns from making jam gave a net benefit of Rs 250 (US$4) from 7 kg of apples – a valuable addition to family incomes. Both vegetables and fruits are plentiful in this area so there is the potential to process produce to sell in markets. In Dasht, women decided to start processing apples, as second-grade fruit suitable for jam making is abundant.

In addition, five field days held in Akhtarzai, Siddiqabad, and Dasht gave farmers the opportunity to see demonstrations of improved crop varieties under both irrigated and *sailaba* conditions (rainfed farming with bunds for water harvesting). The field days also directly involved communities in evaluating the new varieties.

Analyzing lamb market value chains in Aleppo, Syria

Sheep production is a major economic activity in Syria. It provides over 30% of the total value of agricultural production, employs 20% of the total workforce – including many low-income families in rural areas – and is an important source of foreign exchange.

Over the past 20 years, the total value of sheep exports has grown at the rate of 14% per year. The sustained shift from traditional, extensive lamb production systems to semi-industrialized, specialized fattening systems has had a significant impact on productivity and income. Today, all marketed lambs are fattened in intensive systems. Nonetheless, an information gap in the lamb marketing systems has limited policy action to improve the competitiveness and performance of the sector, as well as the welfare of breeders and market agents.

In collaboration with Aleppo University, ICARDA conducted a lamb market study (November 2005 to March 2006) focusing on Aleppo province. This province has the single largest sheep population in Syria (2.2 million head, representing 17% of the country's total sheep population) and is a major domestic and export market. The study aimed to analyze the Aleppo sheep market structure and business practices, identify marketing channels, and determine market competitiveness.

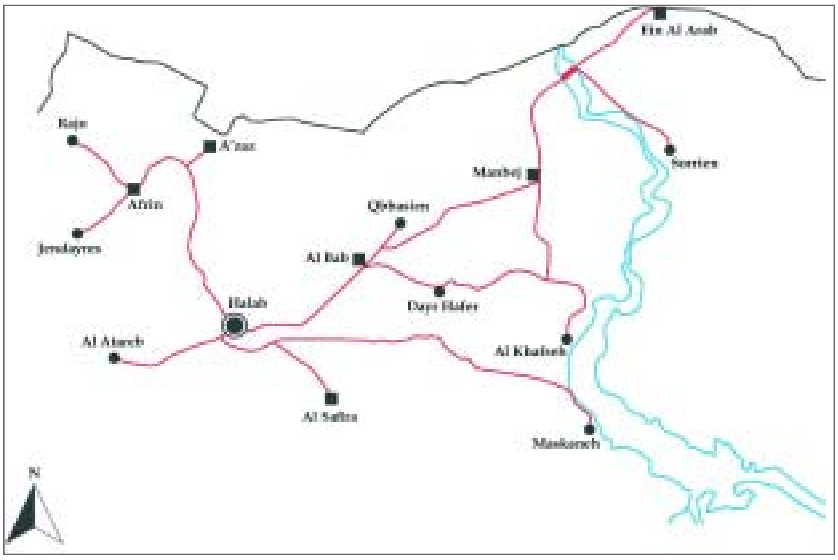


Fig. 5.1. Weekly sheep markets surveyed in Aleppo province.

The project staff conducted rapid rural appraisal surveys and semi-structured interviews in 16 sheep markets. These were the province's two main markets Neqarien and Jebrien (located 15 km east and 12 km southeast of Aleppo city respectively) and 14 small weekly markets in its districts and sub-districts (Fig. 5.1, Table 5.1). The interviewees included a random sample of market agents, including breeders, fatteners, traders, intermediaries, slaughterhouse operators, butchers and exporters. The

Table 5.1. District and sub-district sheep markets in Aleppo province.

District	Sub-district	Market size (ha)	Distance to Aleppo (km)	Business day	Services	Number of intermediaries	Business volume
Afrin		0.50	70	Tuesday	na	15	300
	Jendayres	0.25	90	Monday	na	13	250
	Rajo	0.30	100	Saturday	na	15	250
Al Bab		3.00	35	Thursday	S, Sc	12	600
	Qbbasien	0.30	45	Monday	Sc	10	250
	Dayr Hafer	1.20	50	Thursday	Sc	45	250
Manbej		2.00	80	Saturday	Sc	100	2000
	Al Khafseh	1.50	100	Thursday	Sc	75	1500
	Maskaneh	4.00	85	Tuesday	Sc	65	1200
Ein Al Arab		3.00	175	Sunday	na	40	2500
	Sorrien	1.50	120	Wednesday	na	120	1800
A'zaz		0.30	55	Tuesday	F, Sc	15	500
Al Safira		3.00	45	Monday	F, Sc	100	800
Jabal Sam'an	Al Atareb	0.20	30	Sunday	na	20	500
Aleppo (Neqarien)		10.00	15	Every day	V, F, Sc	60	7000-10000
Aleppo (Jebrien)		1.00	12	Every day	V, S, Sc	50	5000

V: Veterinary unit, S: Stall, F: Fence, Sc: Scale, na: not available
Source: Market survey

information analyzed included market value chains, channels, costs, margins and structure, and business practices, including fattening, transactions, partnerships and profitability.

Around the markets there are many lamb fattening enterprises (*khan*), where unsold animals were also kept. The sub-district bazaars are generally small with no fences or sheep stalls, with the exception of Maskaneh. However, there is a relatively large number of players. For example, in Al Khafseh and Maskaneh there are 75 and 65 intermediaries, respectively.

The structure of the lamb fattening value chain is shown in Fig. 5.2. Sheep breeders supply the lambs to fatteners who prepare them to reach the slaughter weight of about 50-60 kg. Market agent preferences are reflected in their roles and activities. For instance, fatteners prefer to fatten weaned lambs in intensive systems over several production cycles (or batches) over a 90-day period, with starting weights of 25-30 kg and finishing live weights of 55-60 kg per lamb.

The many kinds of traders have diverse functions (Fig. 5.2). Small-scale traders (known as *muareq*) buy and sell animals at the same market. There are some 200 small-scale traders reported in Aleppo province. Although they deal with all sheep types (see Table 5.2), they are mainly involved in the sale of ewes for meat. Other traders, known locally as *shahiin*, buy weaned lambs and ewes at the primary markets and transport them to secondary markets to make a profit. About 25 of these traders are active in Aleppo. A third type of trader, called *qbanji*, buys fattened lambs, processes them at state-run slaughterhouses and sells the carcasses to butchers. About 100 such traders are reported in Aleppo. Although there is only one government slaughterhouse in Aleppo province, used for lambs and culled ewes, a number of private slaughterhouses exist in Al-Marjeh and Qarleq.

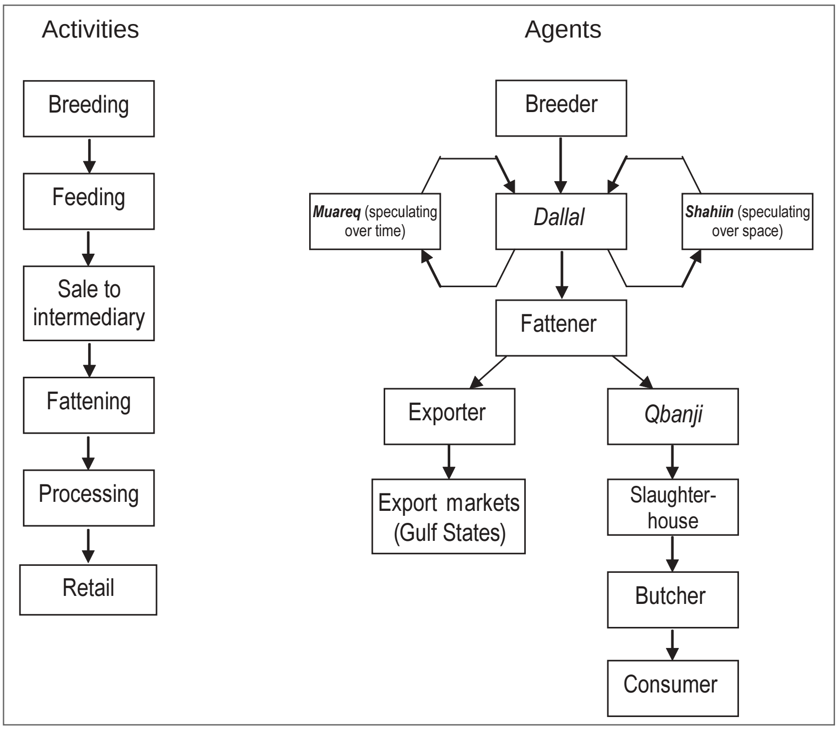


Fig. 5.2. Market value chain in Aleppo province.

Aleppo has 40 exporters who ship lambs to the Gulf markets. As shown in Fig. 5.2, intermediaries or *dallalin* (singular *dallal*) mediate almost all transactions, earning 50 Syrian pounds per head as a commission. There are about 60 intermediaries in Aleppo, which gives an indication of the competitiveness of the market. Because these traders cannot keep animals for long periods and do not have fattening facilities, their small profit margins may turn into net losses as prices fluctuate.

The structure of the market, the large number of sellers and buyers, and the very small margins that dealers gain demonstrate the competitiveness of the Aleppo markets and the absence of concentration of market power in the hands of a few.

The study also found that there is weak institutional capacity in terms of animal health monitoring. Diseases can be transmitted at the market place as animals from different places meet and mix. Intermediaries enforce the return of sick animals to the seller as part of the transaction agree-

Table 5.2. Sheep type and their prices on the Aleppo market.

Sheep type	Unit	Price (SYP)
Female yearling	kg	97
Female lamb (< 1 year)	kg	102
Male lamb (< 1 year)	kg	125
Fattened lamb	kg	115
Culled ewe, old or out of production	kg	85
Ewe without lamb	Head	4130
Ewe with new born lamb	Head	6000
Pregnant ewe	Head	4500
Productive ram	Head	9500
Unproductive/old ram	kg	105

Source: Market survey, average prices (2002-2006).
1 US$ = 50.5 SYP (Syrian pounds).

Sheep market in Aleppo province, Syria.

ment, which is considered quality assurance for the buyer.

The study also showed there were weaknesses in the recording of transactions and prices. Price information is critical for production and marketing decisions. Continuous recording of lamb prices at primary and secondary markets would provide valuable information for policy makers, producers and traders. Yet payments for lambs at the Aleppo markets are not made at the time of purchase, but rather two weeks to one month later. This practice is also a disadvantage for fatteners, particularly resource-poor small-scale fatteners.

Finally, the study highlighted the strong business partnerships between exporters and fatteners, which help capital flow to the sector, linking producers to markets. Understanding these vertical alliances along the value chain is essential for promoting them as instruments that can improve rural livelihoods.

Improving farmers' food security and incomes in Ethiopia, Sudan, Egypt, and Yemen

The project "Technology Generation and Dissemination for Sustainable Production of Cereals and Cool-Season Food Legumes" funded by IFAD for the Nile Valley and Red Sea region was completed in March 2006. The goal was to improve food security and farm household income through developing and transferring technologies to farmers to improve the yields and yield stability of wheat, faba bean, chickpea, and lentil in Egypt, Ethiopia, Sudan, and Yemen. The technologies included information on seeding rate, planting date, fertilizer rates, weed and pest control, irrigation requirements, tillage, and improved crop varieties.

Researchers assessed the impact of technologies on the livelihoods of rural households using indicators such as crop productivity, employment, family income level and its distribution, household food security, and poverty. In collaboration with the national agricultural research programs, 915 house-

Researchers planning a joint assessment of the impacts of improved wheat and legume technologies in Egypt, Ethiopia, Sudan and Yemen.

Table 5.3. Adoption rate of wheat and faba bean technologies (percent of farmers).

Technology component	Wheat			Faba bean		
	Egypt	Sudan	Yemen	Egypt	Sudan	Ethiopia
Variety	68	62	91	100	8	71
Sowing date	74	53	15	44	8	22
Weed control	68	66	na	100	80	100
Pest control	na	64	na	100	63	45
No. of irrigations	88	17	19	na	na	na
Seed rate	65	17	20	58	25	4
Fertilizer	58	44	22	50	0	15

na = not applicable

Table 5.4. Impact of improved technology packages on crop productivity. Yields obtained by adopters and non-adopters, and percentage increase brought by adoption.

Crop	Country	Technology component	Yield (t/ha) Adopters	Yield (t/ha) Non-adopters	Increase (%)
Faba bean	Egypt	Variety	3.3	2.8	18
		Seed rate	3.4	2.8	21
		Weed/pest control	3.3	3.0	10
		Full package	3.4	3.0	13
Faba bean	Ethiopia	Variety	1.7	1.2	42
		Weed	1.6	1.5	7
		Fertilizers	1.5	1.6	-7
		Seed rate	1.7	1.6	6
		Tillage	1.4	1.6	-12
Faba bean	Sudan	Variety	2.7	2.5	8
		Seed rate	3.5	2.6	35
		Weed control	2.6	2.8	-7
		Pest control	2.7	2.7	0
Wheat	Egypt	Variety	6.0	5.2	15
		Seed rate	6.0	5.2	15
		Sowing date	6.0	5.2	15
		Weed control	5.9	5.4	9
		No. of irrigations	5.7	5.6	2
		Full package	6.1	5.2	17
Wheat	Yemen	Variety	3.0	2.1	43
		Seed rate	3.2	2.8	14
		Fertilizer rate	3.2	2.1	50
		No. of irrigations	2.2	3.0	27
Chickpea	Ethiopia	Variety	1.8	1.1	63
		Seed rate	2.0	1.5	25
Lentil	Ethiopia	Variety	1.7	1.0	70
		Sowing date	2.0	0.85	135
		Weed control	1.6	1.00	62

holds in nine locations were interviewed using a pre-tested formal questionnaire and stratified random sampling. The national programs' capacities in impact methodologies, survey techniques, data analysis, and reporting were strengthened by two regional training workshops.

The adoption of the technological packages was selective. Some elements such as sowing methods, improved varieties, and pest control were more widely adopted (Table 5.3).

Effect on crop productivity

The recommended technologies improved crop productivity. In all countries and for nearly all crops and technology components, yields obtained by farmers who adopted all or some components of the package were higher than those of non-adopters. The only exception was faba bean, where weed control in Sudan, and fertilizer application and tillage in Ethiopia generated lower yields for adopters. Improved varieties were important in increasing yields, especially in Ethiopia where rainfed agriculture predominates. Depending on the crop and the country, the yield differences between adopters and non-adopters varied between 8% and 70% (Table 5.4).

An appropriate seeding rate was important, increasing faba bean yields by 6% in Ethiopia and 35% in Sudan. Using the recommended sowing date increased wheat yields by 15% in Egypt and lentil yields by 135% in Ethiopia. Econometric estimates of crop production functions for Ethiopia and Egypt confirmed the net effect of improved varieties and other inputs on crop productivity increases.

Impact on employment

Labor requirements were clearly reduced for certain operations, especially plowing chickpea and lentil in Ethiopia, and harvesting lentil in Ethiopia and wheat in Yemen. There was a substantial increase in labor required for lentil sowing and weeding, chickpea weeding and harvesting in Ethiopia, and for wheat irrigation in Yemen. Compared with traditional practices, the overall effects of the recommended plowing, sowing, weeding, irrigation, and harvesting methods reduced the labor required by 1.5% and 7.8% for chickpea and lentil in Ethiopia, but increased it by 44% in Yemen. Thus, the package did not give a uniform employment outcome for all crops and countries.

Impact on household income

The recommended technologies reduced labor costs in Ethiopia and Yemen, although the direction of change in total production costs per hectare was not clear. In Egyptian wheat production, as a result of higher yields and lower labor costs, returns for adopters were US$300/ha higher than for non-adopters. For the wheat package, adopters in Egypt had average net returns of US$1190/ha, compared to US$830 for non-adopters: an increase of 43%. In Sudan, the corresponding figures were US$510 and US$134 per hectare: an increase of 280%.

Similarly, for lentil and chickpea in Ethiopia and faba bean in Egypt, farmers who adopted the technologies had net returns per hectare of US$451, US$551, and US$962, respectively. These were 17% to 173% above those obtained by non-adopters in each country (Fig. 5.3).

The Gini coefficient was used to estimate the equality aspect of increases in income. Among households that adopted wheat, lentil, and faba bean technologies in Sudan, Ethiopia, and Egypt, respectively, the low Gini coefficient indicated less inequality. Inequality was high for wheat in Egypt and chickpea in Ethiopia, and researchers are studying this issue in more depth.

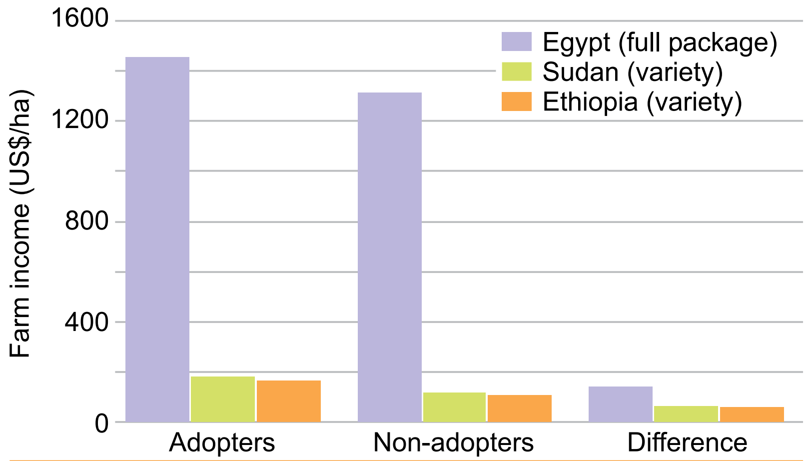


Fig.5.3. Impact of faba bean technology on farm income.

Household food security improvement

The per capita production of each crop was an indicator of project's impact on the food security of farm households. It was calculated by dividing the household's total production for the specific crops by household size. The project has clearly improved food security among adopting farmers. On average, per capita faba bean production in non-adopting households was 428 kg in Egypt and 138 kg in Sudan (both under irrigation), and 44 kg in Ethiopia (under rainfed conditions). Households who adopted the technology had yields that were higher by 8% in Sudan, 13% in Egypt, and 42% in Ethiopia. In Yemen, per capita wheat production was 188 kg, representing an increase of 38%.

In conclusion, impact indicators showed the project was effective in increasing crop productivity, farm income, and food security, and in reducing poverty among technology adopters. Such positive impacts should stimulate wider adoption and greater impacts over time. The study also provided important information on the main constraints to wider dissemination of the technologies to farmers.

For example, in Yemen, the most important constraints are that farmers cannot afford the full package, extension agencies are weak, and competition exists between wheat and cash crops such as potato and onion. For farmers in Egypt, the constraints are the unavailability of inputs, such as improved seeds and fertilizers, at the right time; weakness of extension services; and a shortage of policy measures in the areas of input and output markets, credit, and financial support.

After the project's lifespan of four years, it was clear that farmers were still experimenting with components of the technology, given the variations in adoption rates between countries. Risk aversion may be important in farmer decisions not to attempt the full package early in the adoption process.

A sustainable livelihoods approach to improving livelihoods and preserving natural resources in Algeria, Morocco, and Tunisia

Making a living in most mountain communities is hard. In developing countries in particular, infrastructure, education, health, and other government support rarely reach mountain communities. These communities, therefore need to turn the challenges of their environment into opportunities, for example by making the most of their particular climates by exploiting high-value crops and products. To deliver high quality products, however, they need to improve production and marketing dramatically.

Mountain communities in Algeria, Morocco, and Tunisia teamed up with ICARDA and NARS researchers in a three-year action research project to improve their livelihoods and manage natural resources better. The communities, Lghil Ali in the Biban mountains (Algeria), Ouled H'lel in Kouriminie (Tunisia), and Aît Bazza in the Middle Atlas and Anouggal in the High Atlas (Morocco), are very different, so the sustainable livelihoods approach served as a common framework for the project across the four areas.

The sustainable livelihoods approach has five main thrusts. The first is to get more out of the assets that communities and households already have, such as water, local plant genetic resources, skills, equipment, inputs, and access to credit. The second looks at improving the social assets of communities and households, for example access to credit and extension services. The third thrust is to find new livelihood options, for example diversifying into higher value products, and the fourth to empower vulnerable groups, such as women and young people. The fifth area is to establish links, such as to market chains and mountain development policies. The Maghreb Mountains Project, as it is known, looked at various ways to improve the livelihoods of mountain communities in these five areas.

Lghil Ali, in Algeria, is typical of mountain communities. Although the area is arid, there are many small springs and streams – natural assets – which could be used more effectively. The team of villagers and researchers tested ways to harvest water and carry it from springs or water sources to the fields. They made 'straw pockets' to irrigate vegetables and 'buried stone pockets' to irrigate fruit trees. These are traditional Mediterranean techniques that have recently been resurrected and tested successfully in Tunisia. To make even better use of water, the team restored old irrigation channels and put in pipes from remote springs to fields. These improvements led to greater yields of fruit and vegetables.

In Aît Bazza, Morocco, a survey of local barley and maize varieties turned up two promising varieties of farmers' maize. A study of medicinal and herbal plants also came up with a list of species with commercial potential, for example, thyme, oregano, artemisia, and rosemary. To make the most of these plant genetic assets, farmers will need to learn how to grow

The project is helping farmers intensify production by introducing high-value vegetable crops such as peas.

these species intensively, and how to process the products (by extracting essential oils, etc.), and how to market them.

The research teams also looked at the main crops in the different communities to see where they could be improved. In Aît Bazza, this meant finding better ways to grow potato. In Anouggal, it meant looking at fruit trees and bee keeping. Here, because apples are a commercial crop, production needs to be market-oriented and take advantage of the specific benefits of the mountain environment for growing apples. In this case farmers need better technologies, technical assistance, and training.

When they looked at the social capital of communities, researchers found that formal and informal (customary) organizations and institutions seldom worked together. To demonstrate that working together could open up possibilities, representatives of credit and government development agencies met with farmers in Lghil Ali to tell them about opportunities offered by government institutions.

Although there has been great progress in setting up local development support organizations, these still need help to learn how to plan and manage projects, and to encourage democratic representation and empowerment. In Ouled H'lel, there are no longer any traditional community organizations, so helping to build community-based organizations really paid off. They now operate independently but will still require support for some time. In Anouggal, the combination of giving information to farmers, training, technical assistance, participatory field trials, and exchange visits, proved valuable in building social capital.

Mountain areas do have opportunities to diversify and develop new sources of income. Their unique climate is one area where they have an advantage. For example, they can specialize in late-season crops that fill the gap when main crops in the lowlands are over. By growing new varieties, farmers can get good prices in both local and export markets. They do, however, need to improve production and marketing dramatically to deliver high quality produce.

In Ouled H'lel (Tunisia) and Anouggal (Morocco), there are significant opportunities to brand honey as a specialized product. Farmers would need to improve honey production by managing their hives better, training young bee keepers, and extending the range of plants bees feed on. Another possibility for diversifying into new sources of income is to produce goat cheese.

Honey is a local product with great potential for improving incomes.

Empowering vulnerable groups is a significant challenge. For example, for women to make profits from their skills in weaving local wool and goat hair, major changes will be needed. Only with high-quality design and strong marketing will they be able to penetrate over-crowded markets for handicrafts.

Perhaps most importantly, mountain communities need good links with markets for their products. Commercialization of all high-value products depends on meeting quality standards. In Anouggal, researchers looked at market chains for fruit and walnuts, and the feasibility of labeling and certifying mountain products. At present, fruit and walnuts are either sold to visiting traders or at the weekly market. The volume of production is low and roads are bad, so there are just a few traders who more or less have a monopoly and keep prices low. Nonetheless, these traders are also often farmers' sole source of inputs, credit, and other items, so the situation is not simple.

Another study compared market chains for apples, rural infrastructure, and the role of traders in Anouggal and Taddarine, two villages that are agro-climatically and demographically similar. For various reasons patterns of commercialization were quite different. But, despite the differences, both communities face similar challenges – how to differentiate their products, how to manage cash flow, and how to store apples properly. Between them, the communities have considerable experience. Sharing locally generated solutions could make a big difference in these areas, which tend to be ignored by government extension programs. Farmer-to-farmer and community-to-community knowledge and technology transfer make good sense.

Labeling and certification would also do a lot to promote mountain products. Pressure from the European Union for agricultural products to comply with international quality standards means that these regulations will come sooner or later. So, measures can be taken right now to label and pilot mountain brands under such schemes as the terroir of origin.

There are three promising avenues: the territorial mark, the bio-label for niche products, and conventional trademarks. Many products, for example olive oil, honey, walnuts, apples, cherries, almonds, wool, and meat, are already eligible for at least one of these schemes. Nonetheless, even with labeling and certification, farmers will need better production, processing, and marketing skills before they can depend on these products to improve their livelihoods.

Bejaya, Algeria: a woman processes red pepper into spice to generate income.

Low-cost durum wheat technology for North Africa and West Asia

In most Mediterranean countries, durum wheat is an important part of the diet for both rural and urban people. The five countries of Algeria, Morocco, Syria, Tunisia, and Turkey account for over one-third of global durum consumption and area, and yet Algeria, Morocco and Tunisia are net importers, with Algeria alone accounting for 40% of world imports. ICARDA has been working to improve durum yields for many years, and in 2006 completed a four-year project known as the Integrated Research and Durum Economics Network (IRDEN) project, which was funded by IFAD.

The project aimed to improve the livelihoods of the small-scale farmers who depend on rainfall to grow durum in semi-arid regions. These farmers' yields fluctuate greatly, but are often low because of frequent drought, high temperatures, diseases, and insect pests. The IRDEN project built on the successes of another IFAD-funded project, called WANADIN, which ran from 1996 to 1999 in these five countries.

The IRDEN project promoted participation by involving farmers and their families, researchers, extension staff, local administration, the seed sector, business entities, development agencies, and other stakeholders. ICARDA coordinated the project. The Center selected germplasm, provided scientific information and training, and catalyzed collaboration among institutions in the five countries. NARS in Morocco and Turkey tested the germplasm locally.

Project activities were grouped into five areas (Table 5.5). Staff characterized communities and worked at two pilot sites in each country. They raised awareness of the new technology options through field days, farmer workshops, and constant contact with farmers.

In terms of the project's impact, grain yields from the improved technologies varied according to farmer, location, and variety. However, the average improvement in yields, as compared with those from traditional farming practices, was 30-100% in Algeria, 20-40% in Morocco, 20-30% in Syria, 5-10% in Tunisia, and 15-80% in Turkey (Fig. 5.4). In some cases, for instance the use of varieties resistant to Hessian fly in Morocco, the yield advantage was over 300%.

As farmer awareness of the technologies increased there was a gradual shift to adopting them, with a rate that varied depending on the country and agro-ecology. In North Africa, traditional varieties that are very old (50 years or more) or moderately old (20 years or more) still cover more than 60% of the total durum wheat area. Farmers are, however, switching to the new, higher yielding varieties made available through the project. This was shown by the increasing farmer requests for seed of the new varieties and a rapid rise in the multiplication of seed of improved cultivars in the areas covered by the project, especially by lead farmers in the project communities (Table 5.6).

Farmers bought all the quality seed that was produced, indicating the tremendous impact of the project over a short time period. The lead farmers played a key role, multiplying seed and selling it at competitive prices with payment options that were more advantageous than the ones offered by certified seed sellers in the formal sector.
The project demonstrated that it is viable for communities in these

Table 5.5. Activities of the Integrated Research and Durum Economics Network (IRDEN) Project, 2003-2006.

Theme/activity	Countries	Outcome
Technology transfer	Algeria, Morocco, Syria, Tunisia, Turkey	Increased farmer awareness and adoption of new technology
Seed production and distribution	Algeria, Morocco, Tunisia	Quality seed produced on-farm and marketed to communities at a reasonable price
On-farm value-adding technologies	Algeria, Syria, Tunisia	Durum end-products produced on-farm and marketed in cities
Back-up research	Morocco, Turkey	Germplasm with improved drought tolerance and quality made available to NARS through ICARDA
Capacity building	Algeria, Morocco, Syria, Tunisia, Turkey	- Farmer participation and acceptance of new technologies - Improved technical competence of farmers and extension and research staff - Network of durum researchers - Improved flow of information

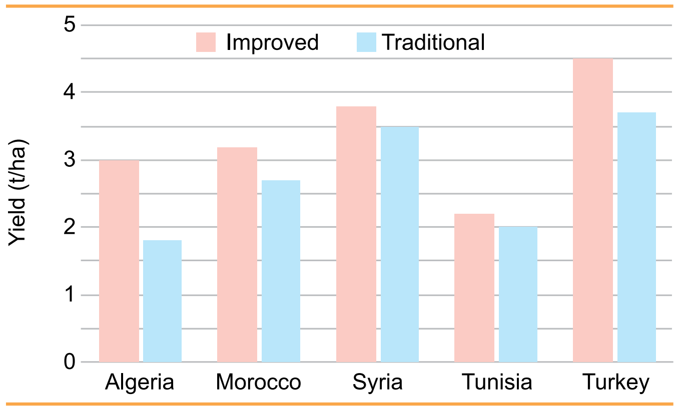


Fig. 5.4. Average on-farm grain yield of durum wheat in 2006 for improved versus traditional technologies at two target sites in each of the five countries participating in the IRDEN project.

countries to establish small-scale seed enterprises. Although seed processed on-farm may not meet the standards of certified seed, the difference in yields is negligible and economically insignificant.

The project also boosted awareness of the importance of exchanging information among farmers and forming groups of common interest. In addition, participatory research helped to shed light on how the value of durum wheat end-products can be enhanced. For example, although the variety 'Biskri' is an old cultivar in Tunisia, consumers prefer its characteristics.

Breeders are therefore working to transfer these characteristics to modern, high-yielding varieties. In other countries, the new varieties – such as 'Douma-1' and 'Bohouth-7' in Syria, and 'GTA Dur', 'Ouarsenis', and 'Sersou' in Algeria – already possess good quality attributes.

Research also showed that consumers prefer on-farm processing of durum end-products (e.g. *couscous*) to standard commercial processing and are willing to pay higher prices for what they perceive as better quality. The fact that this processing is done by women adds a gender equity dimension to this activity.

Table 5.6. Quality seed of durum wheat cultivars produced and distributed to farmers in target communities at start-up (2003) and end (2006) of the IRDEN project (in tons).

Country	2003	2006
Algeria	<1	197†
Morocco	<1	40
Tunisia	<1	320

†197 tons were produced by lead farmers; an additional 153 tons were produced by other farmers

Increased exchange of expertise and information among researchers from the five countries is another positive impact of the project. It also produced a number of publications – including 8 refereed journal articles, 17 brochures, 13 workshop presentations and 3 newspaper articles. Furthermore, 15 students from Tunisia, and one each from Morocco and Syria, conducted research projects or theses on related topics.

Farmer-made durum end-products, valued by consumers, help to improve livelihoods in rural communities.

Looking ahead, there is a need to assess the adaptability to dry areas of the technologies that are currently available – and to adjust them, taking into consideration the specific environmental and socioeconomic constraints of these areas. In North Africa, drought is a quasi-permanent threat that can have disastrous consequences, including total crop loss. Drought mitigation options based on technologies that include crop rotation, reduced tillage, water harvesting, and supplementary irrigation will lessen the negative effect of low rainfall in dry areas.

Mapping poverty through links to resource endowment

Many countries use poverty mapping to design policies that aim to reduce income disparities. However, poverty mapping is based on large-scale household surveys, which are expensive. Yet many countries in CWANA have databases that contain statistics, such as those on agricultural production, prices, and populations, that could provide data for calculating agricultural incomes and compiling maps of rural poverty. The major disadvantage though is that the data is quite generalized and it would only be possible to calculate average incomes over large areas. Poverty 'hot spots' would not show up.

Many studies show that rural poverty correlates strongly with ownership of resources, such as land, water, animals, and machinery. They also show that rural poverty correlates with agroecological variables, such as climate, soil, and water for irrigation. Despite awareness of these linkages, relatively few studies in CWANA have investigated the influence of 'resource poverty' on human poverty and actually used this information to identify poverty 'hot spots'. So researchers deduced that it should be possible to map poverty by combining agricultural statistical data with agroecological information.

To test this new kind of poverty mapping, researchers integrated macro-level socioeconomic statistical data and micro-level environmental data in a case study in Syria.

At the national level (macro level), researchers used the Agricultural Resource Potential Index (ARI) to measure ownership of – or access to – natural resources. This index takes into account resources such as irrigation water, climate, topography, and soils. Then, they used these ratings to estimate Agricultural Productivity Coefficients (APCs) which indicate agricultural production. They plotted the results on a map of Syria divided into 49 climatically uniform sub-regions.

In each sub-region, the distribution of the productivity index correlated with the distribution of the resource potential index. Income from different livestock enterprises was also mapped and incorporated with estimated land-use coefficients. Per capita income was calculated on rural population density. The final set of maps shows total and per capita income distributions from rainfed agriculture, from irrigated agriculture (Fig. 5.5), and from livestock, with and without the resource index.

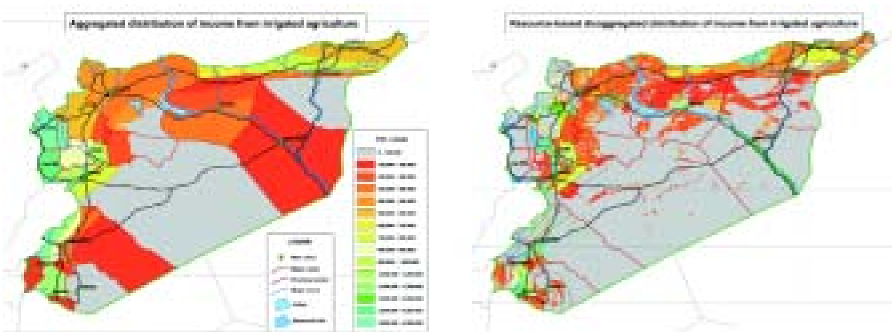


Fig. 5.5. Aggregated (left) and resource-based disaggregated (right) income from irrigated agriculture.

These new poverty maps suggest that rural poverty hotspots in Syria are likely to be found in marginal, resource-poor areas. However, they also occur in areas where there are more resources, but where population pressure reduces the per capita income, for example in the Euphrates Valley.

To cross-check the results, researchers compared total agricultural income of the Khanasser area in northwestern Syria estimated by this method with the results of a recent survey. There was overall agreement, although estimates of per capita income at the village level were somewhat higher than incomes indicated by the survey. Further validation of the method came from household-level nutritional surveys in the same area, which showed that child malnutrition also coincided with areas endowed with few resources.

Mega-Project 6

Knowledge Management and Dissemination for Sustainable Development in Dry Areas

Introduction

ICARDA established a Knowledge Management and Dissemination (KMD) Program in 2005, in response to concerns about the cost-effectiveness and impact of public investment in pro-poor research. The program's primary task is to integrate knowledge management and dissemination into ICARDA's overall research and capacity building agenda. The KMD Program 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 Program 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 Program 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 and technical backstopping, and help promote an informal seed sector, such as community-based seed production, for the benefit of farmers.

Improving women's livelihoods in Afghanistan and Pakistan through better dairy goat production

A three-year project supported by IFAD is helping poor women in marginal and post-conflict areas of Afghanistan and Pakistan to improve their livelihoods by building their skills and knowledge in dairy goat production, milk processing and marketing.

Begun in June 2006, the project involves multidisciplinary teams of scientists and practitioners – from ICARDA, FAO, the national programs of both countries, NGOs from Afghanistan, and Pakistan's National Rural Support Program. The teams are working with women in targeted communities, using community-based, participatory approaches.

Project staff are using secondary data sources, rapid rural appraisal (RRA) and surveys to select and characterize sites. Community leaders and women have demonstrated their interest in participating in the project and establishing women's organizations where they do not already exist. Over the three years, the project will benefit 3,000 women. For the first year, 575 women from 29 villages in four districts in four provinces – Nangarhar and Baghlan in Afghanistan, and Punjab and Balochistan in Pakistan – have been selected.

Training is built into all project activities. This includes training at the local, national, and regional levels. Orientation workshops (2-3 days each) are held in each village to explain the roles and responsibilities of the female facilitators and participating women and to tell them about the project's objectives.

Project staff are gathering and recording local and scientific knowledge on goat production systems. This is based on

Project implementation is managed by specially trained women coordinators.

secondary data, the knowledge and experience of ICARDA scientists, and the findings of the technical committees, the RRAs, and the meetings with communities and women's groups. From the information already collected the researchers have shown that the major technical, institutional and policy options (TIPOs) for improving dairy goat systems are in the following areas: breeds; nutrition and feeding; health; fodder and rangeland; milk processing; and marketing.

During the first year, the project also conducted a baseline survey and a gender-based livelihood analysis to characterize systems, identify problems, and assess potential impact. Before carrying out the livelihood analysis, a training workshop was held. Market studies also began in mid-2006, using a range of research methods.

Participatory research and dissemination is focusing on improving local dairy-goat breeds, the use of feed concentrates, introducing improved fodder crops, planting fodder trees, and vaccination and de-worming. Does and bucks will be selected based on breed characteristics and the overall condition of the flock. The relevant institute or agency will provide quarantine facilities, and animals will be tested for brucellosis and tuberculosis and vaccinated against enterotoxemia and peste des petits ruminants (PPR).

International Assessment of Agricultural Science and Technology for Development

The International Assessment of Agricultural Science and Technology for Development (IAASTD) is a unique, global process that integrates local and indigenous knowledge with institutional and peer-reviewed scientific knowledge. Developed through consultations involving countries from all regions of the world, and over 400 participants, the IAASTD covers crops, livestock, fisheries, forest products, biomass, commodities, and other non-food crops. The Assessment is being conducted over the period 2005 to 2007, and ICARDA has been involved from the start.

The initiative aims to assess how agricultural knowledge, science, and technology can be used more effectively to reduce hunger and poverty, to improve nutrition, health, and rural livelihoods, and to help make development equitable and sustainable in environmental, social and economic terms. It is analyzing lessons from the past, assessing how the world may change over the next 50 years, and providing options for action.

The IAASTD is managed through a Secretariat shared by the World Bank, UNEP, FAO, UNESCO, and four regional institutes. The IAASTD has an intergovernmental governance structure, which resembles that of the Intergovernmental Panel on Climate Change (IPCC), but contains a Bureau similar to the Millennium Ecosystem Assessment's Board of Directors.

The IAASTD will produce one global assessment report, a global summary for decision makers, and a synthesis report. In addition, for each of five world regions, a sub-global assessment report and a sub-global summary for decision makers will be produced. ICARDA acts as the coordinator and focal point for the sub-global assessment for the CWANA region.

The first four chapters of the CWANA sub-global assessment report cover the following: setting the scene, historical and current issues, the plausible future, and looking forward (to examine how policies, institutions and other factors can influence the development and application of agricultural knowledge, science, and technology). The fifth and final chapter examines the role of agricultural knowledge, science, and technology in meeting development and sustainability goals. This report, as well as the CWANA summary for decision makers, will be translated into Arabic and French. Around 60 independent experts, who are participating as volunteers, are helping to write the CWANA chapters, and their names will appear on the reports. The CWANA team is a multi-disciplinary group made up of well-known experts with valuable experience, as well as

Opening session of the 3rd authors' meeting of the IAASTD's CWANA assessment, held at ICARDA-Cairo, December 2006. Left to right: Dr Khaled Makkouk, Coordinator, ICARDA-NVRSRP; Dr Hans Herren, IAASTD Co-Chair and Director of the Millennium Institute; Dr Haniya El-Etribi, President, Agricultural Research Center; and Dr Ahmed Sidahmed, Director, KMD, and ICARDA Focal Point for IAASTD.

early- or mid-career authors with fresh ideas. The latter may well be the people implementing future changes arising from the IAASTD's findings.

Six of ICARDA's senior scientists and directors are contributing to the process. One is the official Focal Point, one is a 'co-ordinating lead author' (having overall responsibility for the chapters), and four are 'lead authors' of designated sections of the assessment chapters. There are also 'contributing authors' who prepare technical information in the form of text, graphs, and data for assimilation by the lead author.

Coordinating the CWANA sub-global assessment report is complex, as the IAASTD process involves six stages. Authors initially prepare a first draft of the report. This is then reviewed by experts and the governments involved in the IAASTD. Authors then prepare a second draft report, which is again reviewed by experts and governments. The final report is then prepared. Finally, the governments review and approve the summary for decision makers.

ICARDA has already held three authors' meetings for the CWANA sub-global assessment. These took place in November 2005 (at ICARDA headquarters), in June 2006 (Amman, Jordan), and in December 2006 (Cairo, Egypt).

The final drafts of the chapters, global and sub-global summaries for decision makers (SDMs), and the synthesis report will be submitted to the IAASTD Secretariat in November 2007 and then to governments and civil society organizations. The last step will be the Final Bureau and Plenary Meeting in January 2008 in Nairobi, where the chapters will be accepted, the SDMs approved, and the synthesis report adopted.

Participants of the 3rd authors' meeting of the IAASTD's CWANA assessment, held at ICARDA-Cairo.

Establishing village-based seed enterprises in Afghanistan

In the absence of formal seed-supply systems in Afghanistan, ICARDA has set up 21 farmer-led seed production and marketing units. These village-based seed enterprises (VBSEs) are producing high-quality seed of improved crop varieties and making it more readily available to farmers.

Developed under the Rehabilitation of Agricultural Markets Program (RAMP), which is funded by the United States Agency for International Development (USAID), these alternative seed-delivery efforts ensure the availability, accessibility, and use of seed. They also encourage farmer-to-farmer diffusion and the adoption of new crop varieties. This, in turn, will raise crop yields, increase and diversify farm income in support of viable rural economies, and make rural households more food-secure. The project, which is fully integrated with RAMP's work to develop markets, has made remarkable achievements during the three years it has run.

The project consulted many different stakeholders and held in-depth discussions with groups of entrepreneurial farmers who were willing to invest in local seed production and marketing. VBSEs were then successfully set up in 21 districts of the target provinces of Ghazni, Helmand, Kunduz, Nangarhar, and Parwan.

Each VBSE comprises 10 to 15 members, giving a total of 254 farmer entrepreneurs. They multiply, clean, treat, and market seed of the improved crop varieties identified by ICARDA and its partners as appropriate for local seed production and marketing within and beyond the target districts and provinces. They also provide quality assurance for the seed they supply.

ICARDA and the agricultural development and extension services of the Ministry of Agriculture helped the VBSE members prepare business plans and market surveys. They also gave the members training in the technical, financial, and management aspects of the enterprises. In 16 training courses, 606 farmer-entrepreneurs as well as other stakeholders (from the ministry and NGOs) gained the knowledge and skills needed to ensure that the VBSEs performed well, and were profitable and sustainable. The project also organized 29 field days, as well as on-site field demonstrations to show how well the improved varieties performed. In total, 1692 farmers received direct training, while an estimated 2786 additional farmers were reached through extension agents.

Each VBSE has allocated, on average, more than 20 hectares of land for producing quality seed of wheat, rice, mung bean, and potato. The seed enterprises are now fully operational, with a total of 1460 hectares cultivated in 2006. This area is distributed among crops as follows: 46% wheat, 23% rice, 20% potato, and 11% mung bean. During 2006, 9855 tons of quality seed were produced, mechanically processed, packaged, tested for quality, stored, and sold directly to farmers, development agencies, and NGOs. Over the three years of the project, the VBSEs produced a total of 15,049 tons of wheat, rice, potato, and mung bean seed (Table 6.1).

Table 6.1. Seed produced by village-based seed enterprises (VBSEs) set up by ICARDA in Afghanistan.

Cropping season	No. of active VBSEs	Seed production (tons)				
		Wheat	Rice	Potato	Mung bean	Total
2003/04	6	753	525	na†	na†	1278
2004/05	17	2188	651	752	325	3916
2005/06	21	3533	2352	3784	186	9855
Total		6474	3528	4536	511	15,049

† VBSEs did not produce the seed of these crops

These low-cost, village-based seed production and marketing enterprises optimize the delivery and diffusion of seed of new varieties. They complement formal seed systems, and offer an alternative that is effective in reaching poor farmers in marginal areas who are beyond the reach of the formal public and private sectors. Farmers do not have to travel long distances, follow formalities, or even have cash in hand to obtain quality seed from the VBSEs. They are able, on the other hand, to identify the crop varieties they prefer, often making in-kind payments. What is more, the seed comes from trustworthy sources, such as fellow farmers in their communities.

Properly cleaned and packaged seed ready for marketing by VBSEs in Afghanistan.

Researchers also assessed the VBSEs' seed production capacity and profitability. They found a total net income of US$0.85 million from the 17 enterprises that were active in 2004/05 and US$2.3 million from the 21 enterprises active in 2005/06.

The VBSEs provided a continuous flow of quality seed of improved varieties at affordable prices, enabling other farmers to improve their yields and incomes. By the end of 2006, average yields for the target crops had risen by an estimated 10%. A total of 245,066 families (1,960,528 individuals) benefited from the quality seed. The multiplier effect of increased yields is expected to reach far beyond the lifetime of the project.

Key to creating awareness and exposing farmers to the new varieties were farmer field days and demonstrations of technical packages. These opened up markets for the seed produced by the VBSEs.

Although the project was very successful, seed demand assessments showed that some farmers do not value quality seed because low prices for their harvests and precarious farming conditions increase risks and uncertainty. Over time, this could undermine the VBSEs' successes and sustainability. For this reason, seed promotion and marketing activities should be at the center of seed operations.

Another key to survival is keeping costs low and profit margins reasonable, to make it possible to offer quality seed at affordable prices.

Continued technical support will be needed to allow the VBSEs to sustain their success over time, and develop into more formal business entities. The majority of the members still need to enhance their capacities in business organization and financial management, seed quality assurance, and seed promotion and marketing.

Impacts of emergency seed and fertilizer supply in Afghanistan

In 2006, ICARDA analyzed the social and institutional effects of supplying emergency seed and fertilizer in Afghanistan, and evaluated its economic impacts. The supplies were distributed in 2002 by the Future Harvest Consortium to Rebuild Agriculture in Afghanistan, which is led by ICARDA, with financial support from USAID.

The Consortium's relief efforts aimed to help overcome the widespread food shortages Afghanistan was facing. These had resulted from decades of civil war and several years of drought in the late 1990s, which had led to displacement of people and disruption of traditional farming systems. The efforts also aimed to quickly improve food and livelihood security by ensuring timely access to seed so as to revive agriculture, the main source of income for the poor.

The Consortium provided 3500 tons of emergency wheat seed for distribution to returned refugees, internally displaced people, or farmers who had lost their seed stocks. It trained farmers to locally multiply more than 5000 tons of quality seed of adapted wheat varieties, then used effective delivery systems to distribute the seed immediately to farmers. It also brought in 53 tons of foundation seed of new germplasm for on-station testing and large-scale evaluation. The International Fertilizer Development Corporation (IFDC) also distributed 50 kg of diammonium phosphate (DAP) and 50 kg of urea fertilizer to needy farmers.

An ICARDA staff inspecting a plentiful grain harvest following emergency seed distribution in Afghanistan.

After the relief operations had ended in 2002, questions remained unanswered. Was seed actually needed in the farming communities? Did the large-scale introduction of seed from outside contribute significantly to yield increases that translated into food security or at least economic gains for the beneficiaries? Have there been social or institutional impacts at the community or village level? Did aid contribute in any way to agricultural reconstruction and the long-term development of the sector?

To answer these questions, ICARDA researchers used a participatory impact assessment framework, based on discussions with stakeholders and focus groups, and surveys of beneficiary households. It applied a partial equilibrium economic surplus method to estimate gains and losses, as well as secondary estimates of demand and supply elasticity and impact attribution based on expert opinions. Simulations helped to estimate the economic impact of the 100% and 50% yield losses reported in a few communities.

The results showed that seed and fertilizer were just two of many household needs at the time. Because of their limited time frame, the relief operations did not directly contribute to strengthening networks among farmers, farmer organizations, and seed vendors. It also did not reinforce self-help mechanisms among beneficiaries. Furthermore, women farmers were not specifically targeted because of the socio-cultural conditions that existed. Nonetheless, at the household level, there was an average wheat yield increase of 41% in the sample. Provincial sub-samples showed yield increases of 2% in Kunar, 5% in Bamyan, 21% in Herat, 38% in Uruzgan, 46% in Samagan, 47% in Badakshan, 49% in Parwan, and nearly 58% in Ghazni.

Net gains per household averaged from US$168 to US$287, with demand and supply elasticity calculated at –0.1 and 0.228 respectively. There was a variation in gains across provinces, explained by differences and changes in grain and straw prices, as well as in yields. When wheat supply was assumed to be more elastic (0.4), estimated surpluses ranged from US$95 to US$161 per household, representing a substantial injection of wealth under the precarious conditions that prevailed in Afghanistan. Crop failures experienced by beneficiaries translated into an average loss of US$60 per household when demand and supply were less elastic. On the other hand, consumption yielded positive gains of US$117 when supply was relatively more elastic (0.4). Based on the total number of beneficiaries, the net social gain estimated was between US$21.8 and US$37.3 million, which is greater than the project's cost. Surplus estimates were highly dependent on the choice of elasticity.

The results showed a wide range of household-level outcomes resulting from the distribution of seed and fertilizer in Afghanistan. The wide range of surplus estimates across households indicates that the poverty, food insecurity, and vulnerability that prevailed in the country at the time of the relief operations may have worsened without the interventions.

Several lessons were learned. First, it is important to take adequate pre-emptive measures. For example, if local seed-security stocks had been in place, this would have limited dependence on external (sometimes uncertain) seed sources. Second, educating the people targeted by relief efforts about the purpose of those efforts can enhance performance in the aftermath of conflicts or disasters. Similarly, intensive short-term training for village institutions and even NGO staff and facilitators would be appropriate in such situations. Third, and ideally, relief operations should include systematic monitoring and evaluation. This would produce indicators that can be used by a wide range of stakeholders, including implementing agencies, researchers, policy-makers, and trainers.

Understanding the lessons learned from these interventions can help improve the capacity of other emergency systems to respond to crises effectively. Because of the realities and conditions in Afghanistan, continuing aid is needed to rebuild agriculture, achieve lasting food security, and improve the livelihoods of the poor. This should include seed-system strengthening to sustain long-term development in this country, which is highly dependent on farming.

Seed treatment and foliar spray for reducing *Ascochyta* blight

Ascochyta blight, caused by the fungus *Ascochyta rabiei*, is a major disease of chickpea worldwide. In 2006, ICARDA conducted a greenhouse experiment to evaluate the combined effects of host plant resistance and seed treatment in reducing yield loss and the number of foliar sprays needed.

Seeds of a susceptible local check ('Baladi'), and moderately tolerant ('Ghab-2') and highly tolerant ('Ghab-3') kabuli chickpea varieties were inoculated with a spore suspension of a mixture of fungal pathotypes I, II, and III at a rate of 800,000 spores/ml. The seeds were then treated with two systemic fungicides: Vitavax 200 FF (20% carboxin + 20% thiram) and Dividend 30 FS (difenoconazole) and grown in a greenhouse. When 10 cm high, chickpea seedlings were sprayed twice with the foliar fungicides Bra (chlorothalonil) or Ort (azoxystrobin). After 24 hours the seedlings were artificially inoculated with an *A. rabiei* spore suspension of pathotype III, at a rate of 500,000 spores/ml. Plants were covered with plastic cages to maintain relative humidity at more than 80%, and the temperature was kept at 20°C for 72 hours. A second fungicide spray was applied before flowering.

The effect of disease inoculation on initial germination and emergence, the effect of seed treatment on infection during early vegetative growth, and the effect of one or two foliar sprays on biological yield and disease severity (using a 1-9 scale, where 1 = least severe and 9 = most severe) were assessed at later growth stages (Figs 6.1 and 6.2).

Seed dressing with systemic fungicides significantly increased the germination of infected seeds in the local check and 'Ghab-2' only. The germination rates for the local, moderately and highly tolerant varieties were, respectively, 73%, 92%, and 100% for treated infected seeds, compared with 57%, 83%, and 97% for non-treated infected seeds. The overall mean germination for infected seeds treated with Dividend 30 FS and Vitavax 200 FF was 94% and 92%, respectively, compared with 88% for the control.

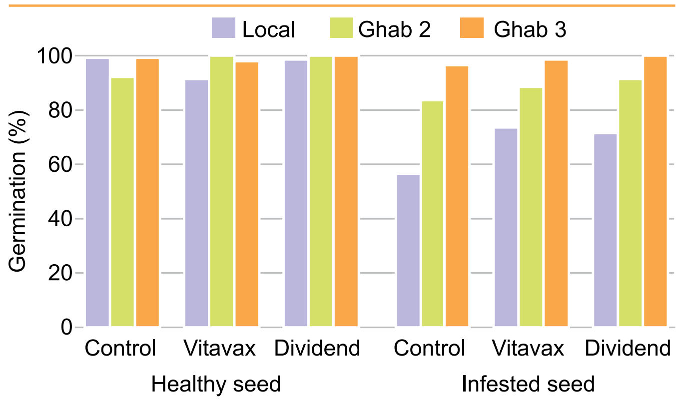


Fig. 6.1. Percentage germination of healthy and inoculated seed with the fungus ***Ascochyta rabiei*** *for three chickpea cultivars with varying levels of tolerance that were treated with two fungicides (Vitavax and Dividend).*

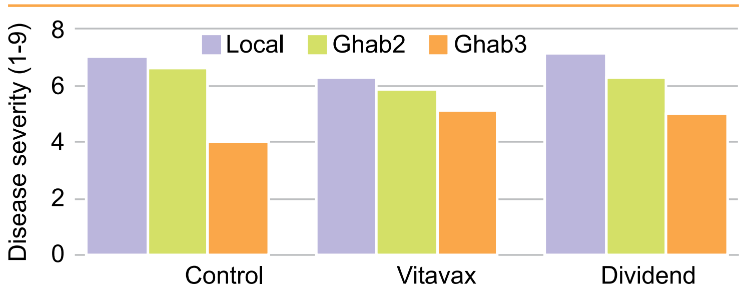


Fig. 6.2. Effects of two fungicides (Vitavax and Dividend) on ***Ascochyta rabiei*** *disease severity on three chickpea cultivars with varying levels of tolerance, scored 45 days after germination. Local: susceptible; 'Ghab-2': moderately tolerant; 'Ghab-3: highly tolerant. Disease severity score: 1=most severe, 9=least severe. Control: no fungicide.*

Seed dressing with Vitavax significantly reduced *Ascochyta* blight severity up to 45 days after emergence (Fig. 6.2). The mean disease severity score for plants of the susceptible local check and the moderately tolerant 'Ghab-2' was 6.25 and 5.86 from treated seeds, compared with 7.00 and 6.62 for non-treated seeds, respectively.

The biological yields from healthy seeds treated with Vitavax and Dividend were 4.02 and 3.53 g/plant, respectively, while the yield of non-treated plants was 3.72 g/plant. Yields with Vitavax were significantly better than with Dividend. Both fungicides increased biomass significantly in plants from infected seeds, but there was no significant difference between fungicides.

Foliar applications of chlorothalonil or azoxystrobin significantly reduced *Ascochyta* blight, and the low disease severity scores were consistent with increased biomass. Disease severity ranged from 6.93 in controls to 2.56 for two sprays with azoxystrobin, and 3.48 for two sprays with chlorothalonil. The biomass was 2.38 g/plant in non-sprayed controls, compared with 4.74 g/plant (99.2% increase) for two sprays with azoxystrobin, and 3.94 g/plant (65.5% increase) for two sprays with chlorothalonil.

Apart from significant protection against pre- and post-emergence damping-off seedling diseases, the fungicides also prevented early vegetative infections by *Ascochyta* blight. Moreover, seed treatment resulted in both significantly stronger vegetative growth and consequently higher biomass yield.

International Cooperation

ICARDA cooperates with NARS, regional and international organizations, civil society organizations, advanced research institutions and other partners worldwide to pursue its research and training agenda. Activities that promote partnerships with NARS within ICARDA's mandate region, including networks (see Appendix 6) and capacity building, are outlined below. Collaborative projects with advanced research institutes, regional and international organizations and other partners are listed in Appendix 5, and the results of joint research with them, as well as between ICARDA and its NARS partners, are presented in the research section of this Annual Report.

ICARDA's research activities at its headquarters and collaborative projects with the NARS cover the entire spectrum from basic and strategic research to applied and adaptive research and, finally, to technology transfer. ICARDA promotes its partnership with NARS through six Regional Programs: North Africa, Nile Valley and Red Sea, West Asia, Arabian Peninsula, Central Asia and the Caucasus, and Latin America. A Highlands Regional Network addresses the problems of agriculture in highland areas.

ICARDA's Regional Programs.

North Africa Regional Program

The North Africa Regional Program (NARP) coordinates ICARDA's activities in Algeria, Libya, Mauritania, Morocco and Tunisia, and is administered through the Center's Regional Office in Tunisia. The objectives of the program are to contribute to poverty alleviation, natural resources conservation, improved crop and livestock productivity, diversification of production systems and incomes, human resources capacity building, and networking in the region.

25th Anniversary of Collaboration between Tunisia and ICARDA

To celebrate the 25th anniversary of collaboration with ICARDA, the Tunisian national program organized a scientific forum on 13 March. H.E. Mohamed Habib Haddad, Minister of Agriculture and Water Resources, Tunisia, and Prof. Dr Adel El-Beltagy, outgoing Director General of ICARDA, opened the forum. Dr Mahmoud Solh, incoming Director General of ICARDA, was present. Twelve Tunisian scientists were recognized by ICARDA for their outstanding contributions to the Tunisia-ICARDA collaborative program. H.E. Haddad presented Dr El-Beltagy with a plaque and a certificate in recognition of his contributions to agricultural research and development in Tunisia.

H.E. Mohamed Habib Haddad, Minister of Agriculture and Water Resources, Tunisia, addressing participants at the opening session of the Tunisia-ICARDA 25th Anniversary celebration. From left to right: Prof. Dr Abdelaziz Mougou, President of IRESA; Prof. Dr Adel El-Beltagy, outgoing Director General of ICARDA; H.E. the Minister; H.E. Prof. Dr Abderrazak Daaloul, State Secretary, Ministry of Agriculture and Water Resources; and H.E. Mabrouk Bahri, President, Tunisian Union of Agriculture and Fishing.

Collaborative Projects

Regional projects
The following collaborative regional projects were implemented in 2006: (i) Sustainable Management of the Agro-Pastoral Resource Base in the Maghreb, Phase II, funded by SDC (covers Algeria, Libya; Mauritania, Morocco and Tunisia); (ii) Regional Program to Foster Wider Adoption of Low-Cost Durum Technologies (IRDEN), funded by IFAD (covers Algeria, Morocco, Syria, Tunisia and Turkey); (iii) Improving the Livelihoods of Rural Communities and Natural Resource Management in the Mountains of the Maghreb Countries, funded by SDC; (iv) Scarce Water in WANA; (v) Assessing Potential of Water Harvesting and Supplemental Irrigation in WANA; (vi) Mashreq and Maghreb (M&M) Project, Phase III: Developing Sustainable Livelihoods of Agropastoral Communities of West Asia and North Africa, funded by IFAD and AFESD (covers Iraq, Jordan, Lebanon and Syria in Mashreq, Algeria, Libya, Morocco and Tunisia in Maghreb); and (vii) Livestock Health and Market Opportunities, funded by IFAD and implemented in collaboration with ILRI.

Bilateral projects with Tunisia/USDA/ARS
ICARDA provides backstopping for three USDA-funded projects: (i) Small Ruminants, Phase II, with ILRI; (ii) GIS for Watershed Management in the Arid Regions of Tunisia, Phase II; and (iii) Biological control of weeds.

Bilateral projects with Mauritania
The Management of Rangeland and Improvement of Livestock (PADEL) project, funded by AfDB, is in its second year. ICARDA provides backstopping in the areas of participatory and community approaches, soil and water conservation, alternative livestock feed resources and rangeland management, as well as human resources development through on-the-job training and visits to North African countries. All activities are implemented at a pilot site, Kiffa East, 600 km east of Nouakchott.

Improved soil and water conservation technologies (stone contour ridges, semi contour-bench terraces and dikes) and forage and rangeland species were introduced. Of the 72 forage, food and rangeland plant species introduced, 30 were successfully planted in nurseries in Ten Souilem, Nouakchott, and represent an *in situ* genebank that will help improve forage and rangeland productivity.

Bilateral projects with Morocco
The INRA-ICARDA-ARS/USDA project on medicinal plants – Biological Diversity, Cultural and Economic Value of Medicinal, Herbal and Aromatic Plants in Morocco – is in its second year. Collaborative activities included the collection and conservation of germplasm, agronomic management of selected herbal and medicinal plants, identification of market opportunities (both local and international) and constraints, scientific visits and training.

Backstopping IFAD development projects in North Africa
NARP organized a traveling workshop for technicians from Taourirt Taforalt (PDRTT: ORV-MAM Moulouya) to Syria and Jordan in collaboration with the M&M national teams in these countries.

The M&M team in Tunisia, in collaboration with IFPRI, conducted field research on the empowerment of agropastoral communities in the Tataouine region. This was funded through an IFAD grant, "Social Capital Assessment: Empowering Communities".

Workshops and Coordination Meetings

NARP helped organize several workshops and coordination meetings. These included

Participants of the M&M III Regional Coordination, Planning and Steering Committee meetings, held in Tunis.

regional and international workshops on natural resources management and policies for sustainable livelihoods, desertification and the international policy imperative, reform of national agricultural research systems, medicinal and aromatic plants, post-harvest technologies, biotechnology, and oasis agriculture. The regional technical coordination and planning meetings of M&M Phase III, IRDEN, SDC Mountain and REMAV projects were held in Algiers. Annual national coordination meetings were held in Algeria, Libya, Mauritania, Morocco, and Tunisia to review results of collaborative research and develop workplans for next year. More than 4000 scientists, research mangers, and extension agents attended the meetings, in addition to representatives from FAO, OSS, UNDP, IRD, AOAD and NGOs.

Enhancing Partnership with NARS and Donors

Donors

Discussions were held with USDA on the development of project proposals on medicinal plants for Tunisia and the Atlas Mountains in Morocco; with the Ambassador of Japan in Tunisia for collaboration in Tunisia and North Africa; with the Spanish Agency of International Cooperation in Nouakchott for collaboration in economic studies and participatory approaches as well as opportunities for diversification of cropping systems in irrigated areas; with GTZ for impact assessment of natural resources management research at community level in Mauritania; with the Swiss Ambassador in Algeria to support the continuation of SDC Maghreb Mountains; and with the World Bank to backstop the PDRC-funded Rural and Community Development Project in Mauritania.

NARS

Contacts were initiated with partners in sub-Saharan Africa to investigate opportunities for collaboration. ICARDA representatives visited CORAF and CERAAS in Senegal and attended the workshop on West and Central Africa Priorities organized by CORAF in Senegal in November, and the NEPAD-AU Conference on Food Security in Africa, in Abuja in December. NARP also contributed to the first CGIAR Medium-Term Plan for West and Central Africa. A project on irrigated forage production in Mauritania was submitted to the Kuwait Fund.

A collaborative program on human capacity building was finalized with ARC-Libya. Proposals will be developed for collaboration with Libya in water management and water harvesting, improving wheat productivity, improving the productivity of small ruminants, and value-added animal products.

A bilateral agreement of collaboration with Algeria was finalized, covering research on wheat, livestock, water management and agricultural policies; human resource development; and enhancement of research infrastructure.

A new Memorandum of Understanding was signed with Morocco. A project proposal on IPM of *Septoria* spp. was developed in collaboration with Tunisia

Nile Valley and Red Sea Regional Program

The Nile Valley and Red Sea Regional Program (NVRSRP) operates through ICARDA's Regional Office in Cairo, Egypt. Its overall objective is to increase the incomes of smallholder farmers in the region by improving the productivity and sustainability of production systems, while conserving natural resources and enhancing the research capacity of national scientists in Egypt, Eritrea, Ethiopia, Sudan, and Yemen.

Collaborative Projects

Several collaborative projects were in operation during the year. These included: Improvement of food legumes and cereal crops, Natural resources management, Control of wild oats in cereals and other winter crops, and Barley participatory breeding in Marsa Matrouh in Egypt; Strengthening client-oriented research and technology dissemination for sustainable production of cool-season food and forage legumes in Ethiopia; Irrigation Benchmark site in Egypt and a satellite site in Sudan; Technology generation and dissemination for sustainable production of cereals and cool-season legumes in the Nile

Valley countries, funded by IFAD, in Egypt, Ethiopia, Sudan and Yemen; and the Water for Food Challenge Program in Eritrea.

The wheat Global Rust Initiative (GRI) was launched in collaboration with Egypt, Ethiopia, Sudan and Yemen.

New Project Proposals

A project proposal on "Improving the livelihoods of rural communities in the Nile Valley and Red Sea region: integrated and sustainable management of croplands and rangeland/livestock, and water resources" was submitted to IFAD for funding. Another proposal on "Improving the livelihoods of the resettled people of the New Hamdab scheme and other resettlement schemes of the Merowe Dam project through sustainable crop, livestock and land (soil+water) management" was submitted by ARC, Sudan to the Government of Sudan.

Workshops and Coordination Meetings

NVRSRP helped organize several workshops and meetings. The topics included: biotechnology and genetic engineering, analysis of adoption and impact data, global authors' meeting of IAASTD, intellectual property rights in relation to participatory plant breeding, scaling up/out agricultural technologies, and meetings of the irrigation benchmark site and the GRI. NVRSRP also played an active role in developing a joint CGIAR MTP for Eastern and Southern Africa.

National coordination meetings were held with Egypt, Sudan, and Eritrea. Over 170 scientists and senior government officials participated. The NVRSRP Regional Coordination Meeting was held at ICARDA headquarters in November. Over 30 scientists from Egypt, Eritrea, Ethiopia, Sudan and Yemen, in addition to ICARDA scientists, participated. The meeting reviewed achievements of the previous year and developed plans for the 2006/07 growing season. The program included a special session on the completed IFAD project, where a detailed impact assessment study in the four countries involved in the project was presented and discussed. The role of these countries in the GRI was also discussed.

Participants of the NVRSRP Coordination Meeting, held at ICARDA headquarters.

National and Regional Traveling Workshops with NARS

A Wheat and Food Legumes Traveling Workshop was held in the newly reclaimed land in El-Bostan and Noubaria (Western Delta) in Egypt. A Cereals and Food Legumes Traveling Workshop was held in Sudan, in which farmers and researchers from Sudan, Egypt, Ethiopia and Yemen participated. A Cereals and Food Legumes National Traveling Workshop was held in Yemen. A Barley Traveling Workshop was conducted in Egypt.

Human Resource Development

Several training courses were conducted in 2006, in Cairo and at ICARDA headquarters, to improve the skills of researchers and enhance regional cooperation. These included non-degree courses, short courses and individual training. The activities were tailored to meet specific needs of the national programs. ICARDA supported a training visit by an Eritrean scientist to the Weeds Research Central Laboratory, ARC, Egypt. In collaboration with the Central Laboratory for Agricultural Climate (CLAC), Egypt, a train-

Cereal and legume traveling workshop participants at a farmer's field in Ribat El-Kalaa village,Yemen.

ing course on greenhouse management was offered to six participants from Afghanistan. A postgraduate student from Yemen underwent one month of training in biotechnology at the Agricultural Genetic Engineering Research Institute (AGERI), ARC, Egypt. Over 50 researchers from the Nile Valley and Red Sea countries participated in various courses at ICARDA headquarters.

West Asia Regional Program

The West Asia Regional Program (WARP) of ICARDA 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.

Collaborative Projects

Collaborative projects with NARS made significant progress during the year. The IRDEN project to foster adoption of low-cost durum wheat technologies in the WANA region, implemented in Turkey and Syria, demonstrated to farmers integrated packages including improved, high-yielding varieties, and options to improve income through value-added products such as *burghul* and *frike*. The project on improved livelihoods and market opportunities for poor farmers in the Near East and North Africa (NENA) region, implemented in Jordan and Syria, identified the main diseases of small ruminants, marketing channels for live animals, and constraints to the control of trans-boundary animal diseases.

The Mashreq-Maghreb III project on developing sustainable livelihoods of agropastoral communities of WANA, during its first year of implementation in Iraq, Lebanon, Jordan and Syria in 2006, selected collaborating communities, provided training on community participatory approaches, and finalized community action plans for technology out-scaling.

The Badia Benchmark Site, established in Jordan, provided valuable information on rainwater management at the watershed and plot levels and on mechanization of water harvesting structures. Over 350 hectares

At the 13th Jordan-ICARDA Biennial Coordination Meeting, ICARDA and Jordanian scientists were recognized for their contributions.

were planted to local shrubs (mainly *Atriplex halimus* and *Salsola vermiculata*) in various water harvesting trials. A Vallerani machine was acquired for mechanization and extension of water harvesting techniques. Joint experiments by ICARDA and the Jordan University of Science and Technology (JUST) on water harvesting techniques for shrub and fruit tree plantations, are in their third season. These experiments are part of thesis research by graduate students, on plant population dynamics.

The Sub-Regional Action Program for West Asia of the UNCCD Pilot Project ended in Jordan and Lebanon in June 2006. Pilot sites established by the project have successfully demonstrated the benefits of water harvesting techniques in limiting soil erosion and securing adequate water supplies for fruit trees, field crops and shrubs, in areas prone to desertification.

The cereal leaf miner, *Syringopais temperatella*, has become a serious pest of wheat and barley in Jordan, particularly in the last two seasons. Infestations, that were apparently restricted to northern Jordan in 2005/06, have spread to southern Syria. More than 10% of cereal fields in southern Jordan are completely damaged; and fields in the north have suffered economic losses. ICARDA will supply a germplasm nursery to be tested for resistance. A concept note was prepared and submitted to potential donors for the study of the insect's biology and ecology, and development of an IPM control package.

ICARDA and the National Center for Agricultural Research and Technology Transfer (NCARTT) continued their efforts in participatory barley breeding. This approach was extended to other crops including wheat, chickpea and lentil. Several promising lines were selected with full farmer participation and discussions are under way for the release and seed production of these lines.

Rebuilding Agricultural Research in Iraq, Palestine and Lebanon

ICARDA is executing six projects in Iraq including capacity building projects funded by AHEAD, ACIAR, JICA and FAO. The Center continued to supply cereal and legume nurseries requested by Iraqi breeders. Nineteen promising lines were identified: six of bread wheat, three of durum wheat, four of barley, three of lentil, and one each of chickpea, *Vicia sativa* and *V. dasycarpa*. ICARDA has also introduced varieties of oats, oilseed crops and other forage species for the diversification of farming systems in Iraq.

A comprehensive proposal for strengthening seed systems (both formal and informal seed production) was developed. ICARDA continued to supply Iraq with breeder and foundation seed of most released varieties of field crops; 30 tons were supplied in 2005/06.

Under the joint ICARDA-ACIAR-Iraq project on crop germplasm and management for improved production of wheat, barley, pulse crops and forage legumes in Iraq, several verification and demonstration trials were conducted in different agroclimatic zones of Ninevah province, with full farmer involvement. These trials helped identify the best adapted varieties, demonstrate the benefits of minimum tillage and appropriate agronomic packages, and highlight the possibilities for crop diversification. These efforts are supported by back-up research conducted

Dr Mahmoud Solh (second left), ICARDA Director General, meets a delegation from Mosul University, Iraq, during their visit to ICARDA. Left to right: Dr Obay Saied Al-Dewachi, President; Dr Nazar Majeed Qibi, Vice President for Scientific Affairs; Dr Mohammed Tayeb Al-Layla, Dean, College of Engineering.

H.E. Talal Al-Sahily (center), Minister of Agriculture, Lebanon, with the participants of the 9th Lebanon-ICARDA Biennial Coordination Meeting.

by ICARDA and Australian scientists. Four zero-till seeders were purchased from India.

Over the last three years ICARDA has conducted agricultural needs assessments and developed a comprehensive program for the rehabilitation of agriculture in Iraq. Several key meetings were held in 2006: with the Minister of Agriculture, with Iraqi delegations, and with international donors including the World Bank, USAID, AusAID, JICA and others, to develop joint projects.

During the 2005 and 2006 seasons, ICARDA trained 146 Iraqis through projects funded by AHEAD, JICA and FAO; and another 70 persons through the ACIAR and Mashreq-Maghreb projects. These included three PhDs and one MSc students. More than 52 Iraqi scientists visited ICARDA or attended workshops organized by the Center.

ICARDA continued to provide support in agricultural research and development to the Palestinian Authority with help from the UNDP Programme of Assistance for Palestinian People. More than 27 persons were trained at ICARDA. Three students (two PhD, one Masters) are conducting their field work at ICARDA.

Over the years, ICARDA has provided germplasm, technical backstopping and training to Lebanon. Researchers from the Center's Terbol and Kferdan stations and from headquarters, have been directly involved. The recent war has severely affected agriculture in many parts of the country. During the 9th Biennial Coordination Meeting, the Lebanese Minister of Agriculture and the Director General of ICARDA stressed the need to develop more collaborative projects to rehabilitate agriculture in the South and the Beqa'a valley, ensure efficient use of water resources, and halt land degradation.

Other capacity building efforts by the regional program included a series of three training courses organized jointly by ICARDA, Wageningen International and SPCRI-Iran, conducted in November and December 2006 in Karaj, Iran. The courses attracted participants from Armenia, Azerbaijan, Ethiopia, India, Iran, Kenya, Morocco and Oman. The courses covered conservation of plant genetic resources, informal seed production, and seed policy/legislation issues.

Arabian Peninsula Regional Program

The Arabian Peninsula Regional Program (APRP) organizes and coordinates ICARDA's activities in seven countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates and Yemen. Collaborative activities include research, capacity building, and human resource

Indigenous forage crops grown with minimum water on a farmer's field in the UAE.

development in water resource management, forage and rangeland management, protected agriculture, and date palm improvement. The program is implemented through offices in Dubai, UAE and Muscat, Oman. ICARDA's Muscat office, which was inaugurated by H.E. Sheikh Salim bin Hilal Al Khalili, Oman's Minister of Agriculture and Fisheries, on 28 March 2006, focuses on the Center's date palm project.

Previous APRP projects, which were funded by AFESD, IFAD and the OPEC Fund, were successful in developing suitable and sustainable technologies for enhancing natural resources management. The new projects focus on enhancing rural livelihood and natural resource management by transferring these technologies to end-users, strengthening national institu-


Introducing soilless production techniques to growers in Oman.

tions, enhancing human resource capacity, and using information technology and networking.

Collaborative Projects

Water-use efficiency, fodder supplies, and land degradation are all important issues in the Arabian Peninsula. To address these, a technology package has been developed in collaboration with NARS for producing indigenous forage species as fodder and pasture crops with minimum use of water. On-farm research on indigenous forage crops continued to progress in 2006. Farmers are now growing indigenous forage Buffle grass (*Cenchrus ciliaris*) using high water-use efficiency techniques. Seed production of indigenous species has been enhanced with the establishment of Seed Technology Units and the technical backstopping provided by the Regional Program.

IPPM techniques for producing high quality cash crops have been transferred to farmers in the mountain areas of Yemen.

Protected agriculture technology packages – soilless culture (hydroponics) and Integrated Production and Protection Management, IPPM – were developed, tested at research centers, and transferred to growers in Arabian Peninsula countries.

To increase farmers' income and support rural development, 18 new greenhouses were installed at farmers' sites in Taez, Yemen, with financial support from the French-Yemen Food Aid Program. ICARDA, in collaboration with AREA, provided growers with technical information and backstopping. A socioeconomic study at the end of the first season showed that pilot farmers had significantly increased their incomes.

On-farm research and demonstration plots for increasing water-use efficiency were continued at the Mikhtan dam site in Yemen. The activities include efficient water utilization for the production of high quality cash crops under protected agriculture, and the adoption of modern irrigation techniques (bubblers) to irrigate grape vine fields.

New Partnerships

A Memorandum of Understanding was signed between ICARDA and Al Sulaiteen Agricultural and Industrial Complex in Qatar, to expand cooperation between the two institutions in agricultural research and production.

A joint proposal was developed with the Public Authority for Agricultural Affairs and Fish Resources, Kuwait, for rehabilitation of degraded rangelands in Kuwait with a special focus on indigenous species. Many rangeland areas in Kuwait were badly affected by oil leaks and oil well explosions during the Gulf war. The proposal is expected be funded by local donors and oil companies in Kuwait.

Feedback from Donors

An IFAD consultant visited the Regional Program in May to evaluate its activities and achievements. His report highlighted the program's success in collecting valuable indigenous germplasm, identifying potential indigenous forage species, increasing water-use efficiency though soilless production in greenhouses, capacity building, and strengthening institutions and NARS networks in the Arabian Peninsula. The report strongly recommended a new project to transfer the technology packages to farmers, especially in Yemen and Oman.

Workshops and Coordination Meetings

The second Steering Committee Meeting of the Protected Agriculture Project in Taez, Yemen, was held in Sana'a in March. The second Technical Coordination and Steering Committee Meeting of the project "Development of Sustainable Date Palm Production Systems in the GCC Countries of the Arabian Peninsula" was held in Muscat.

Human Resource Development

A number of on-the-job training courses on greenhouse installation and production of high quality cash crops were organized by APRP in Egypt, Yemen and Pakistan (Quetta). A total of 40 farmers, researchers, extension staff and NGO personnel participated.

Highland Regional Network

Highlands (> 800 masl) cover over 40% of the agricultural land in CWANA, and are home to the most disadvantaged segment of the region's population. The harsh environment and poor accessibility, to a large extent, explain why these areas have often been neglected by national and international R&D organizations. Harsh conditions promote out-migration and land abandonment. Subsistence is secured from drought-tolerant, low-productivity crops such as barley, as well as fruit trees and vegetables, and from flocks of small ruminants that move to mountain pastures in the summer. Most farms lie 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.

Yet these regions are rich in agrobiodiversity. Farmers predominantly use landraces of various crops, and natural habitats contain a diversity of forages as well as wild relatiives of cultivated crops.

From its early days and until mid-2004, ICARDA operated a Highland Regional Program, which included countries in North Africa, West Asia, and CAC. Because those countries fall within the geographic mandate of other ICARDA Regional Programs, it was decided to consolidate this research within the framework of a Highland Research Regional Network

Growers install a greenhouse in Quetta, Pakistan, with help from ICARDA researchers.

Farmers participating in a field day in Afghanistan.

(HRN). The HRN contributes to improving rural welfare in the highlands of CWANA through sustainable improvements in agricultural productivity. ICARDA staff are located in Iran and Afghanistan, while work in Turkey is coordinated from the headquarters.

Afghanistan

The highland collaborative research program in Afghanistan is managed through ICARDA's office in Kabul. This office also coordinates the activities of the Future Harvest Consortium to Rebuild Agriculture in Afghanistan, and provides technical and logistic support to ICARDA's DfID-funded program on Research on Alternative Livelihood Fund (RALF).

Collaborative Research

ICARDA works closely with national and provincial research and extension institutions of the Afghanistan Ministry of Agriculture, Irrigation and LIvestock (MAIL). There are five ongoing projects: demonstrations and promotion of new technologies; village-based seed production; protected agriculture technology for cash crop production; production and marketing of seed and ware potato (a joint project with the International Potato Center, CIP); and development of staple crops. The first four projects were funded through USAID's Rebuilding Agricultural Market Program (RAMP) and implemented in Ghazni, Helmand, Kunduz, Nangarhar and Parwan provinces. These four projects were successfully completed during 2006 and a high impact is expected. The fifth project, staple crops development, is funded through USAID's Alternative Livelihood Program (ALP). The project is active in Kunar, Laghman and Nangarhar provinces, and will continue until November 2008.

Wheat threshing at Chawki Village-Based Seed Enterprise in Kunar, Afghanistan.

In the demonstration plots project, ICARDA successfully achieved all the deliverables by establishing 966 on-farm demonstrations of nine important crops (wheat, rice, mung bean, potato, onion, tomato, okra, groundnut, and cotton) in 27 districts of five target provinces. More than 8000 farmers were trained over a period of three years. The demonstration plots produced 668 tons of wheat, 270 tons of paddy rice, and 154 tons of mung bean pure seed. By interfacing with the village-based seed production project, this pure seed was made available to producers who multiplied it on about 15,000 ha. The demonstration plots also produced 1313 tons of potato, 959 tons of onion, 630 tons of tomato, 294 tons of okra, 63 tons of groundnut, and 81 tons of cotton, with an average yield 51% higher than farmers' fields. Assuming an adoption rate of 10% in the five target provinces, the improved varieties of wheat, rice, potatoes, onions and tomatoes will generate additional income of US$19,386,876. In addition, the benefits from improved agronomic practices such as seed rate, fertilizer and irrigation in the same provinces are worth an estimated US$26,265,000.

ICARDA established 21 Village-Based Seed Enterprises (VBSEs) – farmer-led seed production and marketing units aiming to produce and rapidly disseminate quality seed of adapted crop varieties, both local and improved. ICARDA provided technical assistance, stock seed, and agricultural machinery to run these enterprises in a sustainable and profitable manner; and also trained VBSE members to diversify crop production in their respective communities and beyond. Collectively, the VBSEs produced over 5000 tons of quality seed of wheat, potato, rice, tomato, onion and mung bean in three years, and also participated in the evaluation of new varieties from international nurseries.

Surveys were conducted on seed demand and supply, and the results used to develop tailor-made business plans for each VBSE. Performance and profitability analysis showed that quality seed production at community level is profitable in Afghanistan because the demand for such seed is high. It is estimated that over 245,000 families will benefit from seed production of the different crops. ICARDA scientists have prepared 'by-laws' for seed producers' associations in local languages that have been adopted by all VBSEs. The VBSEs are registered as legal entities either with MAIL under the Cooperative Law or with the Afghan Investment Support Agency and will continue to produce and market seed with technical support from ICARDA.

A smile of success: "I am helping the community by reducing suffering and pain while earning a licit income without guilt," said Gul Agha of Helmand (left) while marketing his products in Kabul.

ICARDA scientists worked with their counterparts in MAIL to successfully introduce protected agriculture technology that enables farmers to use marginal lands in water-deficit areas. Building on previous work, 42 greenhouses were installed on farmers' land and in MAIL premises. Impressed by the success and profitability of the technology, 30 farmers in Baghlan, Kundus, and Takhar provinces invested their own funds (half the cost of greenhouses) to have greenhouses installed. Another 200 farmers have requested subsidies, credit, cost-sharing mechanisms or other forms of support to acquire greenhouses – indicators of the rapid adoption of protected agriculture technology. Over 300 farmers, and staff from MAIL, extension services and NGOs were trained in greenhouse installation and maintenance, production methods for vegetable cash crops, and produce marketing.

Potato field day in Afghanistan.

It is important to develop an efficient system for producing and marketing potato seed, because this is an important staple in Afghanistan. ICARDA, in collaboration with CIP, has worked on clean seed production, multiplication and marketing of potato seed to reduce dependency on imported seed and ware potato. Seed producer groups in five RAMP target provinces produced and marketed more than 1500 tons of high quality clean seed/ware potato of improved varieties. A micro-propagation facility was established and used for training MAIL staff, and for multiplication of improved varieties. Four improved varieties ('Kufri Chandarmukhi', 'Desiree', 'K. Badshah', 'K. Phukraj') were cultured *in vitro* to produce basic seed. Thirty-three village stores were constructed, and were used to store about 140 tons of seed potato. The stores reduced storage losses from 50 to 5% in all the target provinces.

The Alternative Livelihood Program - East (ALP-E) is being implemented in Kunar, Laghman and Nangarhar provinces. ICARDA scientists, in partnership with MAIL provincial departments, are engaged in development of staple crops through adaptive research, participatory demonstration, and village-based seed production. Promising lines were selected from research trials, and will be further developed and tested for eventual release. To enhance the adoption of improved varieties, the project established 400 demonstrations in farmers' fields, using a participatory approach to achieve rapid dissemination of improved varieties and associated management techniques. Twelve new VBSEs were also established for staple crops, in addition to the 21 established in past years.

Two RALF-funded projects are exploring viable alternatives to reduce farmers' dependence on opium poppy cultivation. One project, "Improved Rural Incomes from Better Forage Production and Sale of Milk Products", examined the possibility of growing high-yielding and nutritive forage legumes in North-Eastern Afghanistan, and of mechanizing yogurt production by using simple, locally produced equipment. Another RALF-funded project, "Cultivation of Mint as a Viable Alternative Livelihood in East and North-East Afghanistan", continued to be active in Helmand, Kunduz, and Nangarhar. The project has established four mint-water production associations, including one for women, that are successfully producing and marketing mint-water in Helmand, Kabul, Kunduz and Nangarhar provinces. The export of mint-water to Peshawar (Pakistan) by the Nangarhar-based association was a new milestone. The project is working to establish a mint-water production facility in the Faculty of Agriculture, Kabul University, to encourage agribusiness entrepreneurship among the graduating students.

New Project

Building on the success of its greenhouse project, ICARDA developed a new project to install 200 greenhouses in three provinces. This was approved for funding by the Counter Narcotic Trust Fund of the Government of Afghanistan.

Turkey

A number of projects were jointly implemented by ICARDA and the Turkish national program in winter and facultative wheat improvement, legume improvement, adoption of low-cost durum technologies (IRDEN Project), and the use of naturally occurring fungi to control Sunn pest.

Under the joint Turkey/CIMMYT/ICARDA International Winter Wheat Improvement Program (IWWIP), germplasm is developed and tested in Turkey and Syria and then dispatched to other sites in areas that produce winter and facultative wheat. A total of 100 sets of international nurseries for different ICARDA crops were provided to partners in Turkish research institutes and universities for testing.

ICARDA also has strong collaboration with the Southeastern Anatolia Project (GuneyDogu Anadolu Projesi, GAP). GAP is mainly a development project operating under the Prime Minister's Office to promote agriculture and improved rural livelihoods in the country's Southeastern Anatolia region. Within the framework of the

Participants of the GAP-ICARDA project planning meeting. Left to right: Ahmet Tokdemir, GAP-ICARDA Coordinator; Manzoor Qadir, Marginal Water Management Specialist, ICARDA; Moussa Mosaad, GAP-ICARDA Project Coordinator; Refet Yilmazoglu, GAP Regional Director, Sanliurfa; William Erskine, Assistant Director General (Research), ICARDA; Mehmet Acikgoz, Group Director of Agriculture, Forest and Economic Development, GAP, Sanliurfa; Abdoul Aziz Niane, ICARDA Seed Unit researcher; and Ashutosh Sarker, ICARDA Lentil Breeder.

ICARDA-GAP collaboration, improved technologies (adapted wheat, barley, lentil, and chickpea varieties along with improved production practices) are being transferred through on-farm trials in cooperation with progressive farmers. ICARDA also provided fodder shrub seedlings, seeds of eight *Atriplex* species, and new forage legumes for testing. The introduced material is monitored and evaluated by GAP staff, local extension personnel, and ICARDA scientists.

The Technical Planning Meeting of the GAP-ICARDA Project was held in Sanliurfa in October. Achievements of the previous season were reviewed, and the workplan for the 2006/07 season was revised. GAP requested new research activities on marginal water use and water harvesting techniques to be included in the revised plan. An IWWIP meeting was held in Ankara to review the results of 2005/06, and finalize the workplan for 2006/07. This was followed by the IWWIP Steering Committee Meeting, which was hosted by DGAR. A Legumes Improvement Meeting was held at DGAR in Ankara to review the results of 2006 and finalize the 2007 workplan for lentil and chickpea.

Participants of the 14th Iran-ICARDA Coordination and Planning Meeting.

Five Turkish scientists from the Ministry of Agriculture and GAP visited ICARDA for training on Utilization of Expert Systems in Agricultural Research and Production, Agroecological Zoning of Turkey, and Drought Mitigation Methodologies.

Two training courses were conducted in Turkey: Methodology of Estimation of Agroecological Zones, and Crop Improvement Research Impact Assessment. An IWWIP traveling workshop in Turkey attracted 46 participants from 18 countries.

Iran

ICARDA's collaboration with the various institutions of the Agricultural Research and Education Organization (AREO) in Iran has led to several achievements over the years. More than 17 new varieties of wheat, barley, food legumes and oilseed crops have been released; over 230 persons (including 46 MScs and PhDs) have been trained.
Efforts to further strengthen activities of the Dryland Agricultural Research Institute (DARI) resulted in an increase of its experiment stations to 12, representing different agroecologies from warm to cold environments, and the introduction of research on oilseed and feed legume crops to diversify the predominant cereals-based farming systems. More than 150,000 hectares are now sown to rapeseed. Several winter-hardy chickpea lines were selected.

ICARDA and Iranian scientists visiting farmers' fields in Dezful, Iran.

ICARDA's collaboration with the Seed and Plant Improvement Institute (SPII) included the supply of wheat and barley germplasm for irrigated conditions in different environments. The Center also provided support to the Seed and Plant Certification Research Institute for training, establishment of seed health laboratories, and drafting of national legislation on variety registration and seed certification. Rapid adoption of the improved varieties and production packages contributed to the wheat self-sufficiency that Iran reached in 2004 and continues to maintain.

Collaborative Projects

Several collaborative projects continued to operate in Iran during the year. A regional program was launched in Dezful on Irrigated Spring Wheat Improvement for Lowlands, focusing on wheat germplasm enhancement and bed planting irrigation techniques. Discussions were initiated between ICARDA, CIMMYT and SPII to develop a regional program for Winter Wheat/Facultative Wheat Improvement for irrigated areas. SPII's expertise continued to be used to monitor rust epidemics and virulence (mainly yellow rust) in Iran and neighboring countries. In collaboration with the University of Vermont, USA, ICARDA continued to work with NARS in Iran, Turkey and Syria to monitor Sunn pest populations and develop an IPM package based on biological control using entomopathogenic fungi to reduce the use of pesticides. Spineless cactus technology was introduced in collaboration with the University of Tehran.

ICARDA and Iran have been operating two projects within the Water Challenge Program, in the Karkheh River Basin watershed. One project is on water productivity, the other on livelihood resilience. Both projects have attracted multi-institutional collaboration and the involvement of a national NGO (CENESTA).

Pakistan

Collaborative Projects

ICARDA's collaborative projects in Pakistan operate through its country office in Islamabad, and cover both highland and lowland areas. The following projects were in operation during the year: Barani Village Development Project; FAO-ICARDA project on Food Security/Poverty Alleviation in Arid Agriculture, Balochistan; Rehabilitation of Agricultural Livelihoods of Women through Dairy Goat Production in Marginal and Post-Conflict Areas of Afghanistan and Pakistan; and Integrated Market-Oriented Feed and Livestock Production in Central and South Asia.

Barani Village Development Project

Emphasis was placed on sustainable seed production and distribution of improved varieties of wheat, mung bean and fodder crops. An informal seed production model was tested for its economic viability. Seed production of sorghum and millet appeared to be less profitable than berseem, oats and maize. Farming communities have shown interest in using mixed feed instead of traditional cottonseed cake to increase milk yield. Trials conducted by farmers showed an increase in milk yield of buffaloes.

The performance of low-cost water regulating structures was monitored and results were encouraging. The work on breed improvement in goats and cattle for meat production led to a significant improvement in liveweight of offspring of local x improved crossbreeds. *Atriplex* and *Acacia* spp. showed promise under saline conditions.

H.E.Oweis Ghani, Governor of Balochistan (4th from right), opened the meeting. With him are (right to left): Dr David Doolan, FAO Representative; Mr Nasser Alam Khan, Director General, AZRC; Additional Chief Secretary of Balochistan; and Dr Adel Aboul Naga and Dr Kamel Shideed of ICARDA.

FAO-ICARDA project on Food Security/Poverty Alleviation in Arid Agriculture, Balochistan

Current activities include development of micro-catchment water harvesting on 15 ha of communal land in Mastung district. About 700 meters of the conveyance system of three farmers was lined with low-cost materials. In collaboration with five farmers, six diversion structures were rehabilitated. These structures will improve soil moisture and crop productivity on 20 hectares of farmland.

Six wheat varieties (Local, GA-2002, AZRI-96, Bhakar, Sham-6 and K-98) were planted at different sites. Farmers rated K-98 and Sham-6 as promising. Four lentil varieties (ILL-8081, Sheraz-96, ILL8076 and ILL-4400) were planted at three sites under floodwater conditions. Farmers preferred ILL-8081 and Sheraz-96 due to their deep red, medium-sized seeds.

Almond, pistachio and olive seedlings (varieties with low water requirements) were introduced from ICARDA and planted at all sites. Establishment rates were 58-86% for almond plants, 14-61% for pistachio and around 96% for olive.

Development of community-based seed enterprises is in progress. Three seed cleaning and treatment machines were used to treat 14 tons of wheat seed during 2006. Improved wheat, barley and lentil varieties were planted on 31 ha for training farmers in seed entrepreneurship.

Three plastic greenhouses (270 m^2 each) were installed in farmers' fields. The cucumber crop harvested from the greenhouses yielded a profit of 25%.

Women's Livelihood Dairy Goat Project

A total of 225 women in 15 villages were selected to undertake collaborative research. Five national and provincial research institutions are collaborating in this project. Strong linkages have been developed with ongoing projects in the area, such as BVDP in Barani area and FAO/UNDP in Balochistan.

Men and women facilitators at Siddiqabad, in a practical training session on how to collect data.

Livestock Feed Project

The project was initiated at two locations (rainfed and irrigated) in 2006. The main emphasis is on improving livelihoods through marketing of milk, meat and fodder with community participation. Scientists from six institutions are involved in the project.

Coordination Meetings

The annual planning and coordination meetings of all four projects brought together national researchers as well as donor representatives.

Human Resource Development

Six male facilitators from integrated research sites and six women from ARI, Quetta attended the Site Facilitators Workshop on Facilitation Skills and Record Keeping Methods. Four women facilitators participated in a training course on food processing jointly organized by ICARDA, FAO and the Agricultural Research Institute, Ternab, Peshawar. Women from the two project sites in Balochistan were trained in drying vegetables (okra, egg-plant, tomato) and making apple jam.

Central Asia and the Caucasus Regional Program

The Central Asia and the Caucasus (CAC) Regional Program, established in 1998, covers Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan in Central Asia; and Armenia, Azerbaijan and Georgia in the Caucasus. The Program has established strong linkages with the NARS in a range of areas: germplasm improvement, plant genetic resources, soil and water management, integrated feed and livestock production, socioeconomics and policy research, and human resource development.

Participants of the Ninth ICARDA-CAC Regional Program Planning Meeting, held in Tashkent, Uzbekistan, April 2006.

Collaborative Projects

Good progress was made in collaborative research projects. A new barley variety 'Adel' was released in Kyrgyzstan. A new genebank facility was inaugurated in Kazakhstan.

In addition, trials continued on more than 50 technologies for on-farm water management, conservation tillage and crop diversification. The results have led to the outscaling of phosphogypsum application for remediation of magnesium-contaminated soils on more than 100 hectares in southern Kazakhstan, and contributed to a dramatic rise in the area sown under alternative crops in Kyrgyzstan (common bean) and Kazakhstan (rapeseed). The adoption of direct sowing of winter wheat into standing cotton increased in Uzbekistan.

New Projects

In order to further widen the scope of the Program's activities, new projects were developed. These included the following: a Challenge Program Proposal for CAC; a new 3-year project for strengthening wheat breeding programs in collaboration with ICARDA, approved by the Center for Science and Technology in Uzbekistan; a project on Sustainable Livestock and Rangeland Biodiversity Management to Combat Natural Resource Degradation and Improve Rural Community Livelihoods in Kazakhstan, Turkmenistan and Uzbekistan, submitted to GEF for funding; a project on Crop Diversification with Food Legumes for Improving Income and Nutrition of the Rural Poor, and Sustainable Productivity of Cereal-Based Cropping Systems in South and Central Asia, jointly developed by ICRISAT, ICARDA, AVRDC and APAARI, submitted to IFAD for funding; the CACILM Multi-country Partnership Framework Support Project, approved by ADB for funding under the first phase of CACILM (ICARDA is the lead center for the Sustainable Land

Participants of the workshop on Community Action in Integrated and Market-Oriented Feed and Livestock Production in Central and South Asia, held in Tashkent, Uzbekistan.

A practical session on machine operation and calibration in Tashkent, Uzbekistan.

Management Research Component under this project); a project on Sustainability of Wheat and Rice on Saline Lands of the Aral Sea Basin, jointly developed by IWMI, ICARDA and IRRI; and a concept note on Conservation Agriculture for Sustainable Land Management in Central Asia, jointly developed by ICARDA and CIMMYT.

Coordination Meetings and Networking

Several regional planning and coordination meetings were organized during 2006, including the ninth ICARDA-CAC Regional Planning Meeting; a National Coordination Meeting on PGR Documentation and Regional PGR Strategy; the Steering Committee Meetings of the two ADB-funded projects on Water and Soil Fertility Management, and Creation of Bright Spots; and a Regional Planning Workshop for the IFAD-funded project on Community Action in Integrated and Market Oriented Feed-Livestock Production in Central and South Asia.

Other important events included a technical meeting on CAC Regional Inventory and PGR Information Network, an international workshop on Improving Conservation Tillage Machinery for Irrigated Agriculture, a National Seed Policy Forum, the Third Regional Conference on Yellow Rust, the Second Central Asian Cereals Conference, and a Regional Workshop on PGR Documentation. A large number of national scientists participated in these events.

More than 1000 farmers, extension workers, and researchers participated in the 28 farmers' field days organized during the year. A Farmers' Fair, the first such event in Central Asia, was organized jointly with IWMI and several other international and national research institutions at the University of Gulistan in Uzbekistan. Over 400 farmers attended.

Human Resource Development

Capacity building efforts included training programs for scientists, extension staff, farmers and government representatives. More than 100 participants from all eight CAC countries attended these events. The training programs covered various areas such as yellow rust management, PGR documentation, socioeconomic and policy research, seed improvement, regeneration methodologies, as well as an English language course for 22 young NARS researchers.

Latin America Regional Program

The Latin America Regional Program (LARP) operates from ICARDA's Mexico office. Its key objective is to partner with NARS, NGOs and private companies in the region through collaborative research projects, human resources capacity building and networking. During the year the program expanded collaboration in several areas, especially legumes and water management.

Collaborative Projects

The collaborative program with EMBRAPA in Brazil has been in operation since 2001. It includes development of barley adapted to the Central Region (Cerrado). New barley lines were tested and promising high-yielding varieties are in the final stage of testing for malting quality.

Collaborative research in Mexico was expanded in 2006. Besides the development of adapted feed, forage and malting barley varieties, a new project was initiated on faba bean and chickpea improvement. Faba bean and chickpea breeders from ICAMEX in Mexico State visited ICARDA headquarters to get acquainted with ongoing research and explore new areas of collaboration. Many of the methodologies learned had direct application to their programs in Mexico. An ICARDA scientist visited Mexico to identify appropriate germplasm. Meetings with legume breeders and supporting agencies were also organized in the States of Mexico and Sonora. There are good opportunities for support in legume research in the region.

Barley fair for farmers in Mexico.

A project to promote barley in northwest Mexico was continued in collaboration with the local farmers' association. The project's participatory approach served as the subject of an MSc thesis for a local student. A Barley Fair – the first in the State – was organized for farmers. Barley evaluation experiments were established and field days organized.

Support Services

Geographic Information Systems Unit

In 2006 the Geographic Information Systems Unit (GISU) supported ICARDA's research agenda with mapping applications in the areas of water resources, poverty, and crop diversification. A case study in Syria, reported in the MP1 section, describes a methodology for outscaling the biophysical potential for supplemental irrigation. In the MP5 section a new approach to poverty mapping is reported that, building on the concept of resource poverty, combines macro-level socioeconomic with micro-level environmental determinants of rural poverty.

During the year, the Unit also mainstreamed its methods for implementing land suitability models in a GIS environment through collaboration with research institutes in Maragheh, Iran (Dryland Agricultural Research Institute, DARI) and Ankara, Turkey (Central Research Institute for Field Crops, CRIFC). These methods aim to assist these countries in their drive to match crops and cropping systems to the biophysical potentials and constraints of their diverse agroecological zones.

The Unit was heavily involved in various training activities. It provided scientific coordination and lectures in the joint CIHEAM-ICARDA Advanced Training Course on 'Characterizing spatial variability for agricultural planning and site-specific crop management in Mediterranean conditions', held in Zaragoza, Spain, 7-17 March 2006. It provided technical support to both ICARDA and CRIFC teams involved in the joint project 'Agroecological zoning of Turkey'. It organized an introductory course on GIS software for ICARDA staff. It hosted a technician of Tottori University, Japan, and a GIS analyst of the National Agricultural Planning Commission, Damascus, for on-the-job training in operational GIS methods. In addition, the Unit provided specialized lectures in other training events at ICARDA.

Computer and Biometrics Support Unit

The major focus of the Computer and Biometrics Support Unit (CBSU) during 2006 was to improve IT security in the Center. Within the scope of the CGIAR ICT-KM project on 'Enterprise security and business continuity', considerable effort was made to maintain and enhance the overall IT security by implementing security standards. This reduces losses caused by viruses and external attacks, and helps ICARDA move towards CGIAR common standards. Documents and diagrams were created for IT assets and resources. Vulnerability, penetration scanning and risk analysis were carried out on the computer network.

Particular attention was directed towards strengthening the networks of the ICARDA outreach offices in Cairo, Kabul and Tashkent and to establish connectivity to the Oracle Applications in a secure manner.

High availability of network and services (Exchange, Proxy/ISA, File Servers, Intranet) was achieved with an uptime of 99%. Old file servers were phased out smoothly. CBSU staff successfully decommissioned the old Proxy server and transferred data to the new ISA server, without disruption, leading to significantly improved network performance. In all, six new servers were installed for the library, Oracle Applications, Intranet, GRU, and photolibrary. The CGIAR Live Communication Server was installed. ICARDA School was assisted in organizing network and servers and installing an e-mail system. Orientation was provided to the new school network administrator. A new Travel System linked to Oracle Applications was developed and implemented by a contractor. On-line budget entry was also implemented.

More than 1000 user requests were serviced. A new 100KVA UPS in the main building and an old 66 KVA UPS in Laboratory 3 were installed.

A 1 Mbit/sec link to Aleppo University was established. The Unit maintained ICARDA Intranet, 'Water Benchmarks of CWANA' and 'RALF Electronic Database' websites. The ICARDA Intranet was moved to a new server.

A CGIAR Performance Measurement System was developed on the request of the CGIAR Secretariat. Data loading for the Project Manager system was updated. The new Payroll System for daily staff at headquarters was developed and is being implemented. In a joint effort with GISU, a new GIS Intranet website was developed; the ICARDA online node for the GeoNetwork project is in its final phase.

Biometrics advisory support was provided to both ICARDA and NARS researchers. Support was provided on a number of specialized software programs for molecular data analysis. Computing modules were developed for analyzing multi-factors in CRD and one-way augmented design.

Experimental designs were offered for various experiments: evaluating photosynthesis activity under drought stress; lentil yield response to variety and agronomic practices; tillage systems under crop rotations; direct seeding with combinations of shrub species; harrowing, irrigation and other management factors; and range nurseries of shrub species.

Statistical analyses were carried out on a large number of datasets. These included international nurseries, trials of lentil and other crops to evaluate efficiency of experimental designs, heritability and gain due to selection; comparing drought versus core collections of bread wheat; wheat yield loss due to YR and ST; evaluating species diversity; olive productivity models; moisture variability and its effect on barley yield; the benefits of phosphogypsum treatment; cereal and forage yields from compost trials with crop rotations to evaluate tillage and nitrogen factors; safflower experiments; dose-response relationships in insecticides; and germination studies on salsola. A technical report on modeling spatio-temporal covariance structures in barley trials was prepared and ten manuscripts were reviewed.

CBSU conducted two biometrics courses for 18 participants, delivered lectures in four courses organized by ICARDA Mega-Projects for 65 participants, and assisted six non-degree individual trainees. Ten MSc and PhD students in genetics and plant breeding, agronomy and socio-economics from Bangladesh, Canada, Ethiopia, Mexico, Sudan and Syria used biometrics support to pursue their studies. An M.Sc. student from Sudan completed his thesis work.

Communication, Documentation and Information Services

Publications and website

ICARDA produced a wide range of publications in 2006, targeted at various audiences. They included, among others: the corporate annual report; 'The Week at ICARDA'; a special issue of *Caravan* on Deserts and Desertification; several newsletters for regional seed networks; an illustrated book on the architectural history of Aleppo; '25 years of cooperation between ICARDA and Syria' (in Arabic); and a series of documents for the External Program and Management Review (EPMR). The publications were distributed widely to NARS and other partners worldwide. A large number of posters were produced for presentation at scientific conferences and book fairs. In addition, over 110 journal articles, conference papers and abstracts were processed for publication or presentation.

The Center's website continued to be popular. The English version of the site received almost 30,000 hits per day on average, during the year. An RSS service was set up to provide users with quick updates.

Media and public awareness

Visits by international journalists and photographers helped raise the Center's profile. Two journalists from the GreenPeace Magazine met management, program directors and senior scientists, and gained a good overview of ICARDA's work. A team from Singing Nomads Productions, Australia, filmed ICARDA's work on genetic resources conservation.

The regional and international media continued to provide positive coverage of ICARDA's work. The clippings are posted on the Center's website (www.icarda.org/Media.htm). Key stories appeared in a number of regional newspapers and magazines.

Multimedia products

Major emphasis was placed on developing and strengthening e-learning resources. Lectures in training courses were re-processed into e-learning modules. Two pilot modules were prepared: 'Business planning for seed enterprises' and 'Variety management and seed quality'. Both are now available online and on CD-ROM.

Video coverage was provided for several key events such as the ICARDA Presentation Day, the 25th anniversary of ICARDA-Tunisia collaboration, and two large-scale farmers' field days in Al-Hassakeh and Idleb provinces in Syria. Key addresses and speeches were compiled on video.

Support Services

Library and Documentation Services

The library added to its collection over 380 books, 910 issues of journals and Annual Reports, and updates of AGRIS databases on CD-ROMs. It fulfilled 1700 requests for literature searches and other services, from NARS scientists and other researchers. The Virtual Library (CD-ROM library) on the Intranet received over 1200 hits (average of 100 per month), and was enriched with additional links to useful reference sources.

ICARDA's new library system, NewGenLib, was made fully operational. Records of the library database were moved to the new system, and are now accessible to all ICARDA users through the Open Public Access Catalog. NewGenLib allows computerization of all library activities, and networking of program libraries at headquarters and 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.

ICARDA continued to work with professional associations, regional fora, and other agencies to strengthen library and documentation services in the CWANA region.

Training

The Center continued to contribute to help strengthen NARS capacity to document, manage and disseminate information. ICARDA staff offered lectures on science writing, PowerPoint presentations, pre-press technology, web design and other aspects to trainees from different CWANA countries. A two-week training course was conducted in November for 12 participants from eight countries. The training covered modern library management systems, NewGenLib, and management of electronic documents and web databases.

Human Resources Development Unit

During the year, ICARDA offered training opportunities to 568 national scientists from 42 countries from the CWANA region, Asia, Asia-Pacific, Europe, and from CGIAR Centers. In addition, 60 national scientists from developing as well as developed countries have been conducting their graduate research training for MSc and PhD degrees jointly between ICARDA and their parent universities. More than 25% of all ICARDA training participants in 2006 were women. ICARDA continued to gradually decentralize its training activities by offering more courses outside headquarters.

In 2006, 13 training courses were offered at headquarters (accounting for about 44% of total participants) and 17 at in-country, regional and sub-regional locations, in close collaboration with NARS. In its continued efforts to respond to the evolving training needs of NARS, the Human Resources Development Unit (HRDU) also facilitated and coordinated implementation of training courses for several externally funded projects.

During the year, 13 training courses and workshops were held at ICARDA headquarters, attended by 175 participants from 24 countries: Afghanistan, Algeria, Egypt, Ethiopia, Eritrea, Iran, Iraq, Jordan, Kazakhstan, Kyrgyzstan, Lebanon, Libya, Morocco, Oman, Pakistan, Palestine, Tunisia, Turkey, Saudi Arabia, Sudan, Syria, UAE, Uzbekistan and Yemen. These courses covered various areas, including crop improvement, integrated crop and livestock production, water management and supplemental irrigation, biotechnology, including genetic transformation and detection of GMOs, experimental design and data analysis, field plot techniques, livelihood characterization and impact assessment, soil analysis, seed processing, storage and marketing, seed sector liberalization, utilization of expert systems, information and library management systems, scientific writing and data presentation. Seventeen training courses and workshops were held at locations outside ICARDA, and were attended by 310 participants from 30 countries: Afghanistan, Albania, Algeria, Armenia, Azerbaijan, Egypt, Eritrea, Ethiopia, India, Iran, Iraq, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Lebanon, Malta, Morocco, Oman, Palestine, Spain, Sudan, Syria, Tajikistan, Tanzania, Tunisia, Turkey, Uganda, USA and Uzbekistan. These courses covered various areas, including hybridization techniques, crop management, integrated pest and disease management, technologies to combat salinity, participatory and community-based approaches, GIS analysis, greenhouse management, seed production, processing and testing, quarantine, impact assessment, and scientific writing.

Collaboration extended beyond NARS to cover several universities, CGIAR Centers, and regional and international centers globally. These included JICA, ACIAR, CLAES, GAP, CIHEAM, University of Vermont, UNESCO, ASDW-Trieste, Italy, GCSAR-Syria, MAWM and IWM-Uzbekistan, CRIFC-Turkey, CIMMYT, the Global Rust Initiative, NARI-Eritrea, FAO, AREO-Iran, Wageningen University, The Generation Challenge Program, Cornell University, Khartoum University in Sudan, and Aleppo, Damascus and Tishreen universities in Syria. Inter-Center collaboration was also strengthened through participation in the Inter-Center Training Group, exchange of training databases, and participation in CGIAR reviews on training and human resources development. ICARDA was actively involved in many CGIAR activities including the Global Open Food and Agricultural University, Virtual University, distance education, e-learning and knowledge management and dissemination.

Appendices

Appendix 1 – Journal Articles

The following list covers journal articles published in 2006 by ICARDA researches, 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

Abang, M.M., M. Baum, S. Ceccarelli, S. Grando, C.C. Linde, A. Yahyaoui, J. Zhan, and B.A. McDonald. 2006. Differential selection on *Rhynchosporium secalis* during parasitic and saprophytic phases in the barley scald disease cycle. Phytopathology 96(11): 1214-1222.

Abang, M.M., M. Baum, S. Ceccarelli, S. Grando, C.C. Linde, A.H. Yahyaoui, J. Zhan, and B.A. McDonald. 2006. Pathogen evolution in response to host resistance genes: Evidence from field experiments with *Rhynchosporium secalis* on barley. Phytopathology 96(6): S2.

Abang, M.M., P. Brunner, C.C. Linde, A.H. Yahyaoui, M. Baum, and B.A. McDonald. 2006. Detecting immigration in field populations of *Rhynchosporium secalis* using assignment tests. Phytopathology 96(6): S2.

Akem, C., M. Bellar, and B. Bayaa. 2006. Comparative growth and pathogenicity of geographical isolates of *Sclerotinia sclerotiorum* on lentil genotypes. Plant Pathology Journal 5(1): 67-71.

Alary, V. 2006. L'adoption de l'innovation dans les zones agro-pastorales vulnérables du Maghreb. Afrique Contemporaine No.219-2006/3. pp. 81-101. (Fr)

Ali, Abdelbagi M., Hala. M. Mustafa, Izzat S.A. Tahir, Abdalla. B. Elahmadi, Mohamed S. Mohamed, Mohamed A. Ali, Asma M. A. Suliman, M. Baum, and Abu Elhassan S. Ibrahim. 2006. Two doubled haploid bread wheat cultivars for irrigated heat-stressed environments. Sudan Journal of Agricultural Research 6: 35-42.

Barrios, E., R.J. Delve, M. Bekunda, J. Mowo, J. Agunda, J. Ramisch, M.T. Trejo, and R.J.Thomas. 2006. Indicators of soil quality: a south-south development of a methodological guide for linking local and technical knowledge. Geoderma 135: 248-259.

Baum, M. and M. Madkour. 2006. Development of transgenic crops and their risk assessment. Arab Journal of Plant Protection 24(2): 178-181.

Belgacem, A.O., M. Chaieb, M. Neffatil, and J. Tiedeman. 2006. Response of *Stipa lagascae* R. and Sch. to protection under arid conditions of southern Tunisia. Pakistan Journal of Biological Sciences 9(3): 465-469.

Bouajila, A., S. Haouas, M. Fakhfakh, S. Rezgui, M. El-Ahmed, and A. Yahyaoui. 2006. Pathotypic diversity of *Rhynchosporium secalis* (Oudem) in Tunisia. African Journal of Biotechnology 5(8): 570-579.

Cross, J.M., M. von Korff, T. Altmann, L. Bartzetko, R. Sulpice, Y. Gibon, N. Palacios, and M. Stitt. 2006. Variation of enzyme activities and metabolite levels in 24 *Arabidopsis* accessions growing in carbon-limited conditions. Plant Physiology 142: 1574-1588

Dutilly Diane, C. 2006. Gestion collective des parcours en zone agro-pastorale: Le cas de Ait Ammar (Maroc). Afrique Contemporaine No.219-2006/3. pp. 103-117. (Fr)

Elloumi, M., V. Alary, and S. Selmi. 2006. Politiques et stratégies des éleveurs dans le gouvernorat de Sidi Bouzid (Tunisie centrale). Afrique Contemporaine No. 219-2006/3. pp: 63-79. (Fr)

Furman, B.J. 2006. Methodology to establish a composite collection: Case study in lentil. Plant Genetic Resources – Characterization and Utilization 4(1): 2-12.

Furman, B.J., M. Ambrose, C.J. Coyne, and B. Redden. 2006. Formation of PeaGRIC: An international consortium to coordinate and utilize the genetic diversity and agro-ecological distribution of major collections of *Pisum*. Pisum Genetics 38: 32-34.

Appendix 1

Guo, P., G. Bai, R. Li, G. Shaner, and M. Baum. 2006. Resistance gene analogs associated with *Fusarium* head blight resistance in wheat. Euphytica 151(2): 251-261.

Hohnwald, S., B. Rischkowsky, A.P. Camarao, R. Schultze-Kraft, J.A. Rodrigues Filho, and J.M. King. 2006. Integrating cattle into the slash-and-burn cycle on smallholdings in the Eastern Amazon, using grass-capoeira or grass-legume pastures. Agriculture Ecosystems and Environment 117(4): 266-276.

Ilbeyi, A., H. Ustun, T. Oweis, M. Pala, and B. Benli. 2006. Wheat water productivity and yield in a cool highland environment: Effect of early sowing with supplemental irrigation. Agricultural Water Management 82(3): 399-410.

Katerji, N., J.W. Van Hoorn, A. Hamdy, M. Mastrorilli, C. Fares, S. Ceccarelli, S. Grando, and T. Oweis. 2006. Classification and salt tolerance analysis of barley varieties. Agricultural Water Management 85(1/2): 184-192.

Khalaf, S.A., O. Abdalla, I.A. Hassan, and F. Jaby El-Haramein. 2006. Comparison of grain quality characteristics of some Iraqi and CWANA selected bread wheat cultivars. Dohuk University, Iraq. 9(1).

Khan, M.A., R. Ansari, B. Gul, and M. Qadir. 2006. Crop diversification through halophyte production on salt-prone land resources. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 1(048) :1-8.

Kharouf, S., F.M. Azmeh, A. Yahyaoui, and M.S. Hakim. 2006. Distribution and physiologic races of wheat yellow rust (*Puccinia striiformis* West f. sp. *tritici*) in Syria during the cropping seasons 1999-2000 and 2000-2001. Journal of Damascus University for Agricultural Sciences 22(1): 363-376. (Ar).

Klewinghaus, A., F. Turkelboom, and A. Skowronek. 2006. A GPS/GIS-integrated approach to the assessment of current soil erosion by water – experiences from Mediterranean NW-Syria. Zeitschrift für Geomorphologie NF 142 (Supplement): 281-305.

Kumari, S.G., K.M. Makkouk, and N. Attar. 2006. An improved antiserum for sensitive serologic detection of chickpea chlorotic dwarf virus. Journal of Phytopathology 154(3): 129-133.

Kumari, S.G., I. Muharram, K.M. Makkouk, A. Al-Ansi, R. El-Pasha, W.A. Al-Motwkel, and A. Haj Kassem. 2006. Identification of viral diseases affecting barley and bread wheat crops in Yemen. Australasian Plant Pathology 35(5): 563-568.

La Rovere, R., A. Aw-Hassan, F. Turkelboom, and R. Thomas. 2006. Targeting research for poverty reduction in marginal areas of rural Syria. Development and Change 37(3): 627-648.

Li, Rong-hua, Guo Pei-pol, M. Baum, S. Grando, and S. Ceccarelli. 2006. Evaluation of chlorophyll content and fluorescence parameters as indicators of drought tolerance in barley. Agricultural Sciences in China 5(10): 751-757.

Liu, X., J.P. Fellers, C.Y. Zhu, N.S. Mutti, M. El-Bouhssini, and M.S. Chen. 2006. Cloning and characterization of cDNA Sencoding carboxypeptidase-like proteins from the gut of Hessian fly larvae [*Mayetiola destructor* (Say)]. Insect Biochemistry and Molecular Biology 36(8): 665-673.

Maccaferri, M., M.C. Sanguineti, V. Natoli, J.L.A. Ortega, B.M. Salem, J. Bort, C. Chenenaoui, E.D. Ambrogio, L.G.D. Moral, A.D. Montis, A. El-Ahmed, F. Maalouf, H. Machlab, M. Moragues, J. Motawaj, M. Nachit, N. Nssarellah, H. Ouabbou, C. Royo, and R. Tuberosa. 2006. A panel of elite accessions of durum wheat (*Triticum durum* Desf.) suitable for association mapping studies. Plant Genetic Resources 4(1): 79-85.

Makkouk, K.M. and S.G. Kumari. 2006. Molecular diagnosis of plant viruses. Arab Journal of Plant Protection 24(2): 135-138.

Mangione, D., S. Senni, M. Puccioni, S. Grando, and S. Ceccarelli. 2006. The cost of participatory barley breeding. Euphytica 150(3): 289-306.

Masri, Z. and J. Ryan. 2006. Soil organic matter and related physical properties in a Mediterranean wheat-based rotation trial. Soil and Tillage Research 87(2): 146-154.

Muehlbauer, F.J., S. Cho, A. Sarker, K.E. McPhee, C.J. Coyne, P.N. Rajesh, and R. Pond. 2006. Application of biotechnology in breeding lentil for resistance to biotic and abiotic stress. Euphytica 147(1/2): 149-165.

Murtaza, G., A. Ghafoor, and M. Qadir. 2006. Irrigation and soil management strategies for using saline-sodic water in a cotton-wheat rotation. Agricultural Water Management 81(1/2): 98-114.

Mustafa, Hala M., Abdelbagi M. Ali, Izzat S.A. Tahir, M. Baum, and Abu Elhassan S. Ibrahim. 2006. Effect of temperature on anther culture of some Sudanese wheat genotypes. Sudan Journal of Agricultural Research 6: 65-68.

Nan, Z. B., A. M. Abd El-Moneim, A. Larbi, and B. Nie. 2006. Productivity of vetches (*Vicia* spp.) under alpine grassland conditions in China. Tropical Grasslands 40 (3): 177-182.

Osman, A.E., F. Bahhady, N. Hassan, F. Ghassali, and T. Al Ibrahimi. 2006. Livestock production and economic implications from augmenting degraded rangeland with *Atriplex halimus* and *Salsola vermiculata* in northwest Syria. Journal of Arid Environments 65(3): 474-490.

Oweis, T. and A. Hachum. 2006. Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. Agricultural Water Management 80(1/3): 57-73.

Qadir, M., A.D. Noble, S. Schubert, R.J. Thomas, and A. Arslan. 2006. Sodicity-induced land degradation and its sustainable management: Problems and prospects. Land Degradation and Development 17: 661-676.

Qadir, M., S. Schubert, A.D. Noble, M. Saqib, and Saifullah. 2006. Amelioration strategies for salinity-induced land degradation. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 1(069): 1-12.

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Sabbouh, M., I. Hassan, W. Choumane, M. Baum, and G. El-Amir. 2006. Genotyping and assessment of genetic diversity in *Pisum* accessions, using AFLP markers. Tishreen University Journal for Studies and Science Research 28(3):207-225.

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Sarker, A. and W. Erskine. 2006. Recent progress in the ancient lentil. Journal of Agricultural Science, Cambridge 144(1): 19-29.

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Sato, T., O.S. Abdalla, T.Y. Oweis, and T. Sakuratani. 2006. Effect of supplemental irrigation on leaf stomatal conductance of field-grown wheat in northern Syria. Agricultural Water Management 85(1/2): 105-112.

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Serra, G., D. Murdoch, F. Turkelboom, F. Travert, Y. Mujawer, and D. Scott. 2006. Sabkhat al-Jabbul, a Threatened Ramsar Wetland in Syria. Sandgrouse 28 (2): 127-141.

Shaaban, S.D., A. Wahbi, A. Sarker, and H. Ghazal. 2006. The efficiency of some legumes and cereal genotypes to phosphorus availability. Emirates Journal of Agricultural Sciences 18(1): 22-27. (Ar)

Siddique, K.H.M., C.L. Hanbury, and A. Sarker. 2006. Registration of Ceora grass pea. Crop Science 46: 986.

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Tahir, I.S.A., N. Nakata, A.M. Ali, H.M. Mustafa, A.S.I. Saad, K. Takata, N. Ishikawa, and O.S. Abdalla. 2006. Genotypic and temperature effects on wheat grain yield and quality in a hot irrigated environment. Plant Breeding 125: 323-330.

Trissi, A.N., M. El Bouhssini, J. Ibrahim, M. Abdul Hai, B.L. Parker, W. Reid, and F. Jaby El-Haramein. 2006. Effect of egg parasitoid density on the population suppression of Sunn pest, *Eurygaster integriceps* (Hemiptera: Scutelleridae), and its resulting impact on bread wheat grain quality. Journal of Pest Science 79(2): 83-87.

Tullu, A., L. Buchwaldt, M. Lulsdorf, S. Banniza, B. Barlow, A.E. Slinkard, A. Sarker, B. Tar'an, T. Warkentin, and A. Vandenberg. 2006. Sources of resistance to Anthracnose (*Colletotrichum truncatum*) in wild *Lens* species. Genetic Resources and Crop Evolution 53(1): 111-120.

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von Korff, M., H. Wang, J. Léon, and K. Pillen. 2006. AB-QTL analysis in spring barley: II. Detection of favourable exotic alleles for agronomic traits introgressed from wild barley (*H. vulgare* ssp. *spontaneum*). Theoretical and Applied Genetics 112(7): 1221-1231.

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Watanabe, N., A.S.G.M. Masum Akond, and M.M. Nachit. 2006. Genetic mapping of the gene affecting polyphenol oxidase activity in tetraploid durum wheat. Journal of Applied Genetics 47(3): 201-205.

Winslow, M. and R. Thomas. 2006. Warning signs for a global future? Regional aspects--Desertification in the Middle East and North Africa. Entwicklung and Landlicher Raum 4: 10-12. (En).

Appendix 2 – Graduate Theses Produced with ICARDA's Joint Supervision

MSc Theses

Iraq, Mosul University

Jameel Mohamed, M. 2006. Selecting resistant Iraqi local cultivars for fungal growth and mycotoxins production. (En).

Morocco, Tetouan, Abdelmalek Essaadi University

Aboukhalid, R. 2006. Studies on genetic diversity of sugar beet (*Beta vulgaris* L.) using microsatellite molecular markers. (En).

Syria, Aleppo University

Hussein, L.O. 2006. The role of micro-catchment water harvesting techniques in combating desertification in Hama and Homs Syrian steppe. 113 p. (Ar).

Khoja, S. 2006. Mechanisms of resistance to chickpea leaf miner (*Liriomyza cicerina* Rond.). (En).

PhD Theses

Iraq, Mosul University

Ibrahim, D. 2006. Agrobacterial mediated transformation of chickpea plant. (En).

Jordan, Jordan University

Shakhatrah, Y. 2006. Genetic diversity assessment among Jordanian wild barley (*Hordeum spontaneum*) genotypes and relationship with morphological traits revealed by SSR molecular markers. (En).

Younis Sultan, M. 2006. Study of the effect of the combination of bio and chemical fertilizers on lentil using Diagnosis and Recommendation Integrated System (DRIS). (En).

Syria, Aleppo University

El-Khalifeh, M. 2006. Common root rot of wheat in Syria and DNA variability within *Fusarium* spp. as a major pathogen. (Ar).

Washington International University

Akintunde, N.A. 2006. Databases – Pre and post relational synthesis. 187 p. (En).

Appendix 3 – Agreements signed in 2006

Agreements of cooperation with international and regional organizations

5 January 2006. Agreement between the Global Forum on Agricultural Research (GFAR) and ICARDA regarding management procedures of the funds deposited in the ICARDA bank account for GFAR.

29 January 2006. Memorandum of Understanding between the Fund for Integrated Rural Development of Syria (FIRDOS) and ICARDA.

Agreements of cooperation with national governments and institutions

Egypt

7 May 2006. Letter of Agreement between the Ministry of Agriculture and Land Reclamation, Arab Republic of Egypt, and ICARDA concerning Cooperation with Central Laboratory for Agricultural Expert Systems (CLAES) and Animal Production Research Institute (APRI), Agricultural Research Center, for development of an Expert System for small ruminants in dry areas.

Pakistan

5 August 2006. Memorandum of Understanding between ICARDA and the University of Agriculture, Faisalabad, Pakistan.

Sultanate of Oman

7 May 2006. Memorandum of Understanding between ICARDA and Al Sulaiteen Agricultural and Industrial Complex (SAIC) in Qatar.

Syria

18 September 2006. Memorandum of Understanding for Networks, Library and Information Systems Connectivity, 2006-2010, between ICARDA and the University of Aleppo.

Tajikistan

5 October 2006. Memorandum of Understanding between ICARDA and the Tajik Agrarian University, Tajikstan.

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 projects are those activities that 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 encompassed in the appropriate sections of the body of this Annual Report.
During 2006, the following Restricted-Fund Projects were operational.

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).
- 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

ADB (Asian Development Bank)

- Enabling communities in the Aral Sea basin to combat land and water resource degradation through the creation of 'bright' spots
- Improving rural livelihoods through efficient on-farm water and soil fertility management in Central Asia

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
- Host resistance, epidemiology and integrated management of faba bean, chickpea and lentil diseases
- ACIAR Project Planning Meeting for Crop Improvement in Iraq
- 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

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
- Technologies for the targeted exploitation of cereal and pulse landraces
- Associate Expert in host resistance, epidemiology and integrated management of faba bean, chickpea and lentil diseases
- 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

DPI (Department of Primary Industries)

- Digitizing International Trials

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 Agropecuaria / Brazilian Agricultural Research Corporation

- Cooperative activities between ICARDA and EMBRAPA

Appendix 4

BIOVERSITY INTERNATIONAL

- Improving access to ICARDA genebank data through SINGER

CANADA

CIDA (Canadian International Development Agency)

- Global Rust Initiative

CGIAR-Canada Linkage Funds

- Characterization and molecular mapping of drought tolerance in chickpea

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
- Durum wheat Quantitative Trait Loci research

HarvestPlus

- Identification of barley germplasm accessions with high concentration of β-carotene, iron and zinc
- Identification of lentil germplasm accessions with high concentration of β-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

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

SLP (Systemwide Livestock Program)

- Low-toxin grasspea for improved human and livestock nutrition and ecosystems health in drought-prone areas in Asia and Africa
- Enhancing livelihoods of poor livestock keepers through increased use of fodder in Syria

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 6th Framework International Cooperation (INCO)

- 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)

EC 6th Framework Program

- Waste water use and recycling by using new generation greenhouse systems, adapted to the requirements of the Mediterranean partner countries

FAO (Food and Agriculture Organization of the United Nations)

- 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
- TCP "Strengthening seed supply in the ECO region with special emphasis on Central Asia"
- Expert Group Meeting on Harnessing Biotechnology and Genetic Engineering for Agricultural Development in the Near East and North Africa
- Workshop to strengthen national plant breeding and biotechnology capacity through policy advice for countries in the Caucasus and Central Asia (Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, Turkmenistan and Turkey)
- Regional Meeting on Need Assessment for Agricultural Research for Development (ARD) in the Central Asian and Caucasian (CAC) Region
- Workshop about the methods of negotiation in Tunis
- Applied research to focus on approriate methods of stand establishment under rainfed conditions of key forage species for Syria and KSA
- Organization of the "assessment and design strategies to strengthen national plant breeding and biotechnology workshop" for countries in the Caucasus
- Applied research to focus on approriate methods of stand establishment under rainfed conditions of key forage species for Syria and KSA

FAO/GFAR (Food and Agriculture Organization of the United Nations/Global Forum on Agricultural Research)

- Support to the CAC Regional Agricultural Information System
- Regional Meeting on Need Assessment for Agricultural Research for Development (ARD) in the Central Asian and Caucasian (CAC) Region
- Oat and Vetch Network for the Maghreb Countries (REMAV) 2006 meeting

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

- Exploration of genetic resources collections at ICARDA for adaptation to climate change

BMZ (Federal Ministry for Economic Cooperation and Development)

- Post-Doctoral Fellow in Analysis of allelic gene expression in ICARDA-mandated crops

GLOBAL CROP DIVERSITY TRUST

- Inventory of *ex-situ* collections of Annex 1 crops in Central Asia and the Caucasus (CAC)
- Establishment of a Regional Plant Genetic Resources Information Network for the CAC Region
- Improving the facilities of genebanks in the CAC Region
- Organization of a workshop to develop a global *ex situ* conservation and utilization strategy for food legumes (chickpea, lentils, faba beans and grass pea)
- Development of a global strategy for the *ex situ* conservation of barley

GEF/UNDP (Global Environment Facility/United Nations Development Program)

- PDFB - combating desertification in South Asia: the agriculture-environment nexus

GCC (Gulf Cooperation Council)

- Development of sustainable date palm production systems in the GCC countries of the Arabian Peninsula

Appendix 4

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
- 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)

- 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
- 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
- Institutional contract: rural sector performance assessment and rural finance sector review for Afghanistan
- Community action in integrated and market oriented feed-livestock production in Central and South Asia
- Program for rehabilitation of agricultural livelihoods of women in marginal post-conflict areas of Afghanistan and Pakistan

IFPRI (International Food Policy Research Institute)

- Organization of a workshop on Reorienting Research Management and Agricultural Innovation Systems in Central Asia and the Caucasus

INDIA

- Lentil improvement research

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
- Barely activities in Ethiopia

JAPAN

Japan Attributed Funding

- 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

RDA (Rural Development Administration)

- Collaboration in barley research

LIBYA

Agricultural Research Center

- Collaboration in agricultural research and capacity building

MAURITANIA

- Technical assistance to Projet Gestion des Parcours et Développement de l'Elevage (PADEL)

MOROCCO

MCGP (Morocco Collaborative Grants Program)

- 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
- Management of scarce water resources in agriculture in the WANA region

PAKISTAN

- Cooperation in the applied research component of the Barani Village Development Project (BVDP)

SWITZERLAND

SDC (Swiss Agency for Development and Cooperation)

- 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

ZIL (Swiss Centre for International Agriculture), ETHZ (Federal Institute of Technology)

- Research Fellowship project on improving resistance to barley scald

ETHZ (Federal Institute of Technology)

- Improving small ruminant productivity in dry areas through cost-efficient animal nutrition and improved quality of milk and dairy products

THE NETHERLANDS

- Tailor Made Training: the improvement of farmers based seed production scheme and revitalizing informal seed production
- Training Programme on plant genetic resources and seeds: policies, conservation and use

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
- Convening the Designing Integrated Financing Strategies (DIFS) - North Africa Training Workshop

UNCCD Sub-Regional Action Program (SRAP) for West Asia

- Integrated natural resources management program to combat desertification in Lebanon and Jordan (pilot projects)

Appendix 4

UNESCO

- Sustainable Management of Marginal Drylands (SUMAMAD) - Khanasser Valley Integrated Research Site, Syria
- Sustainable Management of Marginal Drylands (SUMAMAD) - Zeuss Koutine site, Tunisia
- 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
- Fifth International SUMAMAD Workshop

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 RAMP (Rebuilding Agricultural Markets Program), 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
- Clean seed production, multiplication and marketing for increased potato production in Afghanistan

USAID ALP (Alternative Livelihoods Program), Afghanistan

- Promoting improved production of staple crops

USAID

- Global Rust Initiative

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

USDA/FAS (United States Department of Agriculture/Foreign Agricultural Service)

- Biological diversity, cultural and economic value of medicinal, herbal and aromatic plants in Morocco
- Biological diversity, cultural and economic value of medicinal, herbal and aromatic plants in Tunisia
- Research on improving productivity of oats as a priority forage species in Tunisia
- Biological control of weeds with plant pathogens
- GIS for watershed management in the arid regions of Tunisia

Appendix 5 – Collaboration with Advanced Research Institutes and Regional and International Organizations

CGIAR CENTERS AND REGIONAL/INTERNATIONAL ORGANIZATIONS

ACSAD (Arab Center for Studies of Arid Zones and Dry Lands)

- 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 regional program for sustainable development of drylands in WANA

CIAT (International Center for Tropical Agriculture)

- ICARDA participates in the Systemwide Programme on Participatory Research and Gender Analysis (PRGA), 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)

- 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 research on water use efficiency
- Collaboration in mapping adaptation of barley to drought environments.
- Joint training courses and information exchange

CIMMYT (International Maize and Wheat Improvement Center)

- ICARDA and CIMMYT have formalized their collaboration within the ICARDA-CIMMYT Wheat Improvement Program for Central and West Asia and North Africa
- An ICARDA barley breeder was seconded to CIMMYT
- CIMMYT participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus (CAC), 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 CAC, coordinated by ICARDA

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 the FAO/CIHEAM SARD 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 the NEMEDCA Drought Network

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- 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
- Collaboration in a Technical Cooperation Program on conservation agriculture in Karakalpakstan, Uzbekistan

ICBA (International Center for Biosaline Agriculture)

- Collaboration in research on salinity management in agriculture

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)

- ICRISAT participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in CAC, 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, 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 CAC

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 CAC
- 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 CAC
- 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

IRRI (International Rice Research Institute)

- IRRI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in CAC
- ICARDA is participating in the Generation Challenge Program, 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 Program on Water and Food

IWMI (International Water Management Institute)

- IWMI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in CAC
- 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 Educational, Scientific and Cultural Organization - Man and the Biosphere Program)

- Collaboration in sustainable land management of marginal drylands

United Nations University

- Collaboration in research on water harvesting, watershed management and sustainable land management of marginal drylands

World Vegetable Center - formerly Asian Vegetable Research and Development Center (AVRDC)

- AVRDC participates in the CGIAR Consortium for CAC.
- Collaboration in horticulture assessment in Asia and the Near East Region

AUSTRALIA

University of Adelaide, Waite Institute

- Plant health management for faba bean, chickpea and lentils
- Better crop germplasm and crop management for improved production of cereals and legumes in Iraq
- Joint evaluation of barley germplasm for low rainfall and salt stressed environments
- Development of micronutrient-dense barley germplasm and micronutrient analysis

CLIMA (Centre for Legumes in Mediterranean Agriculture)

- Development and conservation of plant genetic resources in the Central Asian Republics
- Evaluation and regeneration of pulse legume accessions
- Collaboration to widen the genetic base of lentil in India, Nepal and Bangladesh
- Improving lentil and *Lathyrus* in the cropping systems of Nepal
- Plant health management for faba bean, chickpea and lentils
- Better crop germplasm and crop management 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 Industries (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

Australian Winter Cereals Collection, Tamworth

- Development and conservation of plant genetic resources in Central Asia
- Technologies for the targeted exploitation of bread wheat landrace germplasm
- Introgression of novel resistance to leaf rust, Hessian fly, Russian wheat aphid, stem sawfly, and use of DART technology

Department of Primary Industries (DPI), Horsham, Victoria

- Improvement of 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 ecogeographic diversity studies
- Development and conservation of plant genetic resources in Central Asia

Appendix 5

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

Southern Cross University

- Genetic manipulation of pulses for improved flavor and color
- Novel barley germplasm for food and malt

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.
- Management of scald and net blotch in barley

Department of Agriculture, Western Australia

- 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

Landwirtschafflich-Chemische Budesversuchsanstalt (BAVL)

- Safety duplication of ICARDA's faba bean germplasm collection

University of Natural Resources and Applied Life Sciences (BOKU), Vienna

- Production diversification in small ruminant production; decentralized and participatory breeding plans

BELGIUM

University of Ghent

- Collaboration in research on watershed management

University of Leuven

- Joint supervision of MSc graduate research on integrated assessment of land degradation
- Collaboration in research on watershed management

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

Crop Development Center, University of Saskatchewan, Saskatoon

- Evaluation of chickpea for *Ascochyta* blight resistance
- Morphological and molecular characterization of drought tolerance in chickpea

DENMARK

Ris□ National Laboratory, Plant Biology and Biogeochemistry Department

- Integrated cereal disease management in Eritrea

Danish Institute of Agriculture Sciences (DIAS)

- Characterization of wheat yellow rust and its population dynamics; and integrated disease control in wheat and barley

Royal Veterinary and Agriculture University, Department of Agricultural Sciences, Plant and Soil Science Laboratory

- Genetic mapping in barley, genotyping & data analysis

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
- Development of a dataset on allele diversity of candidate genes

CNRS (Centre National de la Recherche Scientifique

- Diagnostic tools for variability among virus causal agents in food legumes

Institut National de la Recherche Agronomique (INRA)

- Morphophysiological traits associated with constraints of Mediterranean dryland conditions in durum wheat.
- Establishment of a composite collection and genotyping of faba bean genetic resources
- Collaboration in research on water use efficiency

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

Biologische Bundesanstalt für Land - und Forstwirtschaft (BBA) (Federal Biological Research Centre for Agriculture and Forestry), Department of Plant Virology, Microbiology and Biosafety, Braunschweig

- Identification of chickpea viruses in Tunisia and wheat viruses in Turkey using PCR and sequence analysis

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

IPK-Gatersleben

- Association mapping and microarray analysis in barley

University of Frankfurt am Main

- Genomics of cold and drought tolerance in chickpea and lentil

University of Hannover

- Development of transformation protocols for chickpea and lentil
- Research on impact assessment of natural resource management research

University of Hohenheim

- Increasing the heterozygosity level of barley to exploit heterosis under drought stress

University of Kiel

- Molecular genotyping of a composite collection of lentil germplasm

ITALY

University of Bologna

- Improving durum wheat for water use efficiency and yield stability; development of drought tolerance
- Drought tolerance mechanisms and gene expression under drought conditions in wheat

Istituto Sperimentale per la Cerealicoltura, Sezione di Fiorenzuola d'Arda

- Mapping adaptation of barley to drought environments

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

Udine University

- Allelic imbalance and gene expression in barley

JAPAN

Japan International Research Center for Agricultural Sciences (JIRCAS)

- Use of Dreb technology for improving ICARDA legume crops
- Evaluation of genetic resources and physiological analyses for enhancing drought tolerance in wheat germplasm

Yokohama City University

- On-farm and *in-situ* conservation of wheat genetic resources in the Near East

Tottori University

- Collaboration on human resource development programs for arid land sciences

REPUBLIC OF KOREA

Rural Development Administration

- Collaboration in barley research

Appendix 5

NETHERLANDS

Wageningen University and Research Center

- Collaboration in research on water harvesting and watershed management
- Collaboration in international training program on plant genetic resources and seeds: policies, conservation and use
- Collaboration in training program on improvement of farmers based seed production scheme and revitalizing informal seed supply of local crops and varieties in Ethiopia

Department of Plant Science, Laboratory of Plant Breeding, Wageningen

- Collaboration in mapping adaptation of barley to drought environments

RUSSIA

N.I. Vavilov Research Institute for Plant Industry (VIR)

- Genetic resources exchange, joint collection missions and genetic resources evaluation and documentation
- Bread wheat eco-geographic diversity studies

SPAIN

University of Barcelona

- Barley stress physiology and mapping adaptation of barley to drought environments
- Drought tolerance mechanisms and gene expression under drought conditions in wheat

University of the Basque Country

- Enhancing the productivity of sheep milk production systems and quality of dairy products

University of Cordoba

- Durum grain quality
- Establishment of a composite collection and genotyping of faba bean genetic resources

UdL-IRTA (University of Lleida and Institut de Recerca i Technologia Agroalimentaria - IRTA)

- Mapping adaptation of barley to drought environments
- Improving durum wheat for water use efficiency and yield stability

SWITZERLAND

Station Fédérale de Recherches Agronomiques de Changins (RAC), Nyon

- Safety duplicate collection of ICARDA's accessions of *Lathyrus* and *Vicia*

Swiss Federal Institute of Technology (ETH), Animal Nutrition Department

- Feeding systems and quality of sheep milk products

Swiss Federal Institute of Technology (ETH), Institute of Plant Sciences/Phytopathology

- Molecular characterization of fungal pathogens (scald, *Septoria*)
- Population dynamics of *Rhyncosporium secalis*

University of Bern

- World Overview of Conservation Approaches and Technologies (WOCAT) Consortium
- Joint supervision of graduate student research on social, environmental, and economic impacts of water harvesting techniques

UNITED KINGDOM

Centre for Arid Zone Studies, University of Wales, Bangor

- Research on alternative livelihood options in Afghanistan

Birmingham University

- Joint training program in ecogeographic surveys
- Co-supervision of PhD research in taxonomic identification of the *Viciaceae*

CABI Bioscience

- Entomopathogenic fungi for Sunn pest control

Macaulay Land Use Research Institute

- Feeding systems for small ruminant production in the dry areas

Macaulay Research Consultancy Services Ltd.

- Research on alternative livelihood options in Afghanistan

National Institute of Agricultural Botany

- Allelic imbalance assay and gene expression analysis in barley

Natural Resources Institute, UK

- Research on alternative livelihood options in Afghanistan

Rothamsted Research

- Drought tolerance mechanisms and gene expression under drought conditions in wheat

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

- Studies to understand the evolution and domestication of cultivated and wild lentil, peas, and chickpea
- Research on water productivity
- Collaboration in assessment of horticulture options

Cornell University

- Research on alternative livelihood options in Afghanistan

University of Delaware

- Use of information technology for improving water use efficiency

University of Florida, Gainesville

- Forage systems research and modeling

University of Hawaii

- Collaborative training program for visiting scientists and graduate research fellows from Iraq

Michigan State University / IPM Collaborative Research Support Program

- Integrated pest management in Central Asia

University of St. Paul, Minnesota

- Evaluation and characterization of *Hordeum spontaneum* for disease resistance genes

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

- Collaboration in research on water harvesting and watershed management

University of Vermont

- Sunn pest biocontrol

Virginia Polytechnic

- Joint research on assessing the impact of agricultural research on poverty

University of Wisconsin

- Breeding and testing of dairy sheep genotypes; feeding system improvement; milk product quality control

Washington State University

- Rust and *Stemphylium* blight resistance in lentil.
- Breeding of chickpea for *Ascochyta* blight resistance
- Resistance to Russian wheat aphid, and molecular biology of Hessian fly
- Research on alternative livelihood options in Afghanistan

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, Manhattan, Kansas / Kansas State University

- Resistance to Russian wheat aphid and molecular biology of Hessian fly

USDA/ARS Cereal Rust Laboratory, Minnesota

- Pathoyping CWANA wheat stem rust

USDA/ARS, Stillwater, Oklahoma

- Screening and biotype characterization of Russian wheat aphid

USDA/ARS Plant Stress and Water Conservation Laboratory, Lubbock, Texas

- Climatological analysis as a tool for agricultural decision-taking in dry areas

USDA/ARS Grain Legume Genetics and Physiology Research, Pullman, Washington

- Exploitation of existing genetic resources of food legumes
- Inheritance and mapping of rust and *Stemphylium* resistance genes in lentil

USDA/ARS Western Regional Plant Introduction Station, Pullman, Washington

- Conservation and collection of plant genetic resources in CAC

Yale University

- Collaboration in research on poverty, rural livelihoods and impact 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 inter-country 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)

	2006	2005
REVENUES		
Grants (Core and Restricted)	23,817	28,882
Other revenues and gains	1,650	932
Total revenues and gains	25,467	29,814
EXPENSES AND LOSSES		
Program related expenses	23,978	26,772
Management and general expenses	3,261	2,796
Other losses and expenses	-	661
Total expenses and losses	27,239	30,229
Indirect costs recovery	(774)	(898)
Net expenses and losses	26,465	29,331
EXCESS REVENUES OVER EXPENSES	(998)	483

Statement of Financial Position (US$x000)

	2006	2005
ASSETS		
Current assets	25,187	26,370
Property & equipment	3,446	3,511
Employee savings scheme funds	5,793	5,359
Total assets	34,426	35,240
LIABILITIES AND ASSETS		
Current liabilities	13,251	14,337
Long-term liabilities	9,242	7,976
Total liabilties	22,493	22,313
Net assets	11,933	12,927
Total liabilities & net assets	34,426	35,240

Statement of Grant Revenues, 2006 (US$x000)

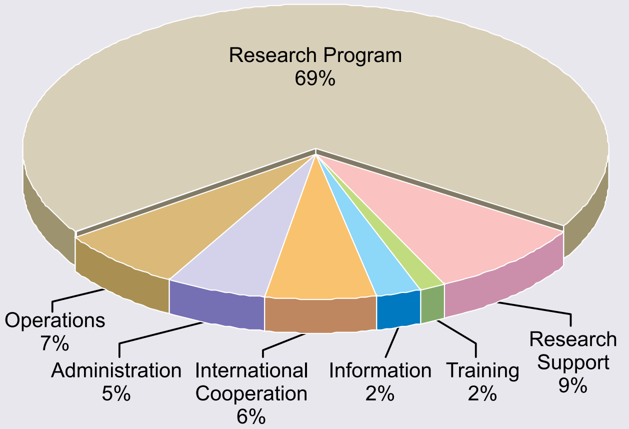
DONORS	Amount
Arab Fund	1,215
Asian Dev. Bank	287
Australia*	975
Austria	138
Belgium*	256
Canada*	847
CGIAR	820
Challenge Program	1,015
China*	10
Denmark*	386
Egypt*	250
Ethiopia	11
European Commission	139
FAO	389
France*	247
GCSAR - Syria	85
Germany*	526
Global Crop Diversity Trust	76
GM-UNCCD	151
Gulf Cooperation Council	347
IDRC	134
IFAD	1,511
India*	118
INRA-INRAT	271
Int. Nutrition Foundation	14
Iran*	165
Italy	43
Japan*	403
JIRCAS	55
Mauritania	30
Miscellaneous	134
Morocco	210
Norway*	887
Pakistan	241
South Africa*	20
Sweden*	549
Switzerland*	564
Syria*	500
The Netherlands*	514
The OPEC Fund	179
Turkey*	225
UNEP	63
UNESCO	64
United Kingdom*	2,889
University of Minnesota	47
University of Wisconsin	16
USAID*	2,853
USDA	252
World Bank*	2,696
TOTAL	23,817

* Donors that provided core funds

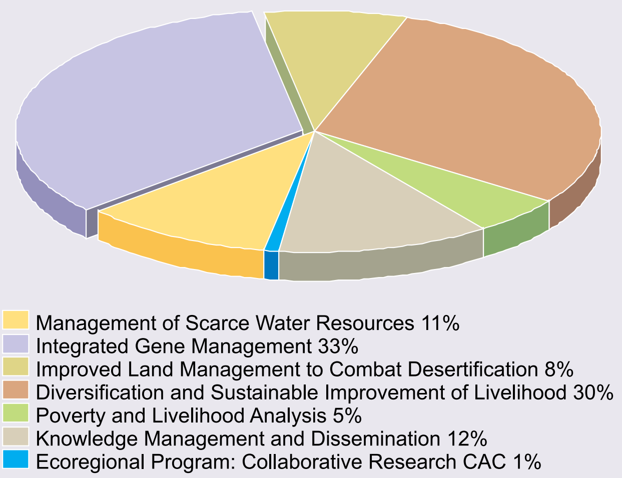
Appendix 7

Expenditure by Program and Activities

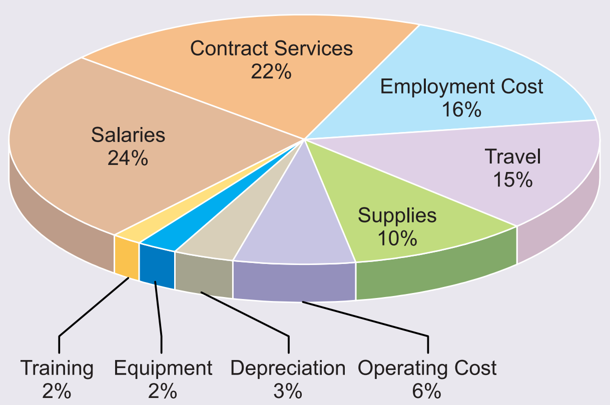
(Total Expenditure US$ 27.239 million)



Expenditure by Mega-Projects

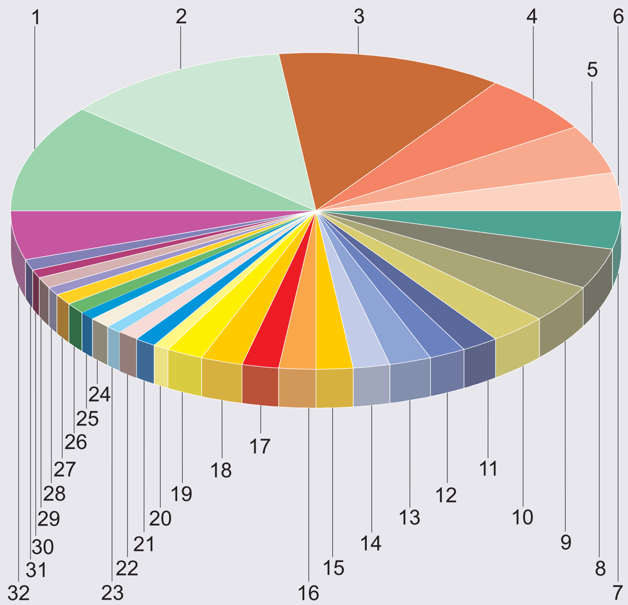


Expenditure by Expense Category



Donor Contributions 2006

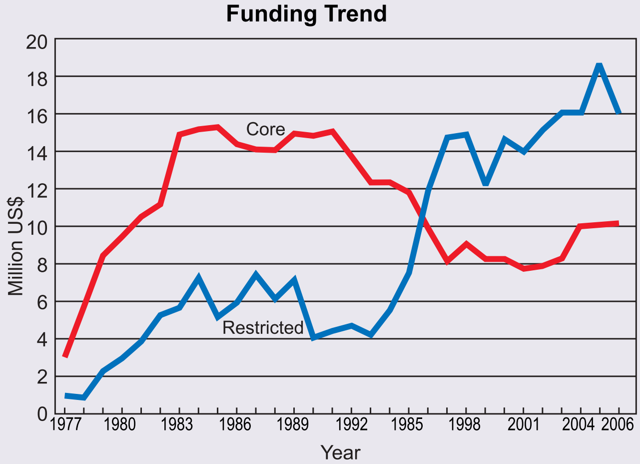
(Total Grant Revenues US$ 23.817 million)



1 World Bank* 11%
2 United Kingdom* 12%
3 USAID* 12%
4 IFAD 6%
5 Arab Fund 5%
6 Challenge Program 4%
7 Australia* 4%
8 Norway* 4%
9 Canada* 4%
10 CGIAR 3%
11 Switzerland* 2%
12 Sweden* 2%
13 Germany* 2%
14 The Netherlands* 2%
15 Syria* 2%
16 Japan* 2%
17 FAO 2%
18 Denmark* 2%
19 Gulf Coop. Council 2%
20 Asian Dev. Bank 1%
21 INRA-INRAT 1%
22 Belgium* 1%
23 USDA 1%
24 Egypt* 1%
25 France* 1%
26 Pakistan 1%
27 Turkey* 1%
27 Morocco 1%
29 OPEC Fund 1%
30 Iran* 1%
31 GM-UNCCD 1%
32 Other donors 5%

* Donors providing core funds

Funding Trend



Appendix 8 – Board of Trustees

On 31 December 2006, the composition of ICARDA's full Board of Trustees was as follows:

Dr Guido Gryseels
Chairperson
Director
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Appendix 8

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(963-21) 5741480 (R)
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Fax: (963-21) 2225105/2213490
E-mail: m.solh@cgiar.org

Appendix 9 – Senior Staff (as of 31 December 2006)

Headquarters, Aleppo, Syria

Director General's Office

Prof. Dr Adel El-Beltagy, *Director General (until May 2006)*
Dr Mahmoud Solh, *Director General (from May 2006)*
Dr William Erskine, *Assistant Director General (Research)*
*Prof. Dr Magdy Madkour, *Assistant Director General (International Cooperation)*
Dr Ahmed El-Ahmed, *Assistant Director General (Government Liaison)*
*Dr Adel Aboul Naga, *Senior Advisor/Consultant*
Ms Houda Nourallah, *Administrative Officer to the Director General and Board of Trustees*

Project Development and Coordination Unit

Dr Elizabeth Bailey, *Head*
Ms Ilona Kononenko, *Grants Management Officer*

Corporate Services

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

Finance Department

Mr Vijay Sridharan, *Director*
Mr Mohamed Samman, *Treasury Supervisor*
Mr Ahmed El-Shennawy, *Associate Director*
Mrs Imelda Silang, *Finance Officer, Budget, Donor Reporting and Outreach*

Management of Scarce Water Resources and Mitigation of Drought - MP1

Dr Theib Oweis, *Director*
Dr Manzoor Qadir, *Marginal Water Management Specialist*
Dr Adriana Bruggeman, *Agricultural Hydrology Specialist*
Dr Hamid J. Farahani, *Specialist in Irrigation and Water Management*
Dr Bogachan Benli, *Post-Doctoral Fellow (Irrigation and Water Management)*
Mr Akhtar Ali, *Water and Soil Engineer*

Integrated Gene Management - MP2

Dr Sanjaya Rajaram, *Director, and Director of Joint ICARDA/CIMMYT Wheat Program*
Dr Ali Abdel Moneim, *Forage Legume Breeder*
Dr Rajinder Malhotra, *Senior Chickpea Breeder*
Dr Salvatore Ceccarelli, *Barley Breeder*
Dr Stefania Grando, *Barley Breeder*
Dr Miloudi Nachit, *Durum Wheat Breeder*
Dr Osman Abdalla, *Bread Wheat Breeder*
Dr Amor Yahyaoui, *Senior Cereal Pathologist*
Dr Michael Baum, *Biotechnologist*
Dr Mustapha El-Bouhssini, *Entomologist*
Dr Ashutosh Sarker, *Lentil Breeder*
Dr Sripada M. Udupa, *Biotechnologist/Geneticist (based in Morocco)*
Dr Moussa Guirgis Mosaad, *Visiting Scientist*
Dr Flavio Capettini, *Barley Breeder (based in Mexico)*
Dr Bitore Djumahanov, *Cereal/Legume Breeder (based in Tashkent)*
Dr Mathew Musumbale Abang, *Post-Doctoral Fellow-Legume Pathologist*
Dr Akinnola Nathaniel Akintunde, *International Crop Information System and International Nursery Scientist*
Dr Fekadu Fufa Dinssa, *Post-Doctoral Fellow-Barley Breeder*
Dr Kamel Chabane, *Biotechnologist*
Dr Shaaban Khalil, *Consultant-Faba Bean Breeder*
Dr Bassam Bayaa, *Consultant-Legume Pathologist*
Dr Mohamed Khalifa, *Consultant-Durum Breeder*
Dr Masanori Inagaki, *JIRCAS Scientific Representative*
Dr Safaa Kumari, *Manager of the Virology Laboratory*
Dr Maria Von Korff Schmising, *Post-Doctoral Fellow - Analysis of Allelic Gene Expression in ICARDA Mandated Crops*
Mr Fadel Al-Afandi, *Research Associate*
*Mr Berhane Lakew Awoke, *Visiting Research Fellow*
*Dr Peiguo Guo, *Visiting Scientist*

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*
Mr Bilal Humeid, *Research Associate*
Dr Siham Asaad, *Head of Seed Health Laboratory*

*Left during 2006

Appendix 9

Improved Land Management to Combat Desertification - MP3

Dr Richard Thomas, *Director*
*Dr James A. Tiedeman, *Range Management Scientist*
Dr Francis Turkelboom, *Soil Conservation/Land Management Specialist*
Dr Ashraf Tubeileh, *Post-Doctoral Fellow-Nutrient and Water Flows in CWANA*
Dr Jurgen Anthofer, *Researcher on Integrated Natural Resource Management in Dry Mountainous Areas*
Dr Celine Dutilly-Diane, *Socioeconomist, CIRAD/ICARDA*

Diversification and Sustainable Improvement of Crop and Livestock Production Systems - MP4

Dr Colin Piggin, *Director*
Dr Mustafa Pala, *Wheat Based Systems Agronomist*
Dr Luis I□iguez, *Senior Small Ruminant Scientist*
Dr Asamoah Larbi, *Pasture and Forage Production Specialist*
Dr Barbara Ann Rischkowsky, *Senior Livestock Scientist (Small Ruminants Management)*
Dr Najibullah Malik, *RALF Project Manager*
*Dr Aggrey Ayuen Majok, *Project Coordinator/Epidemiologist, ICARDA-ILRI*
Mr Tsutomu Tamada, *Associate Expert*
Dr Safouh Rihawi, *Research Associate I*
Ms Azusa Fukuki, *Research Associate*
Ms Monika Zaklouta, *Research Associate I*
*Ms Birgitte Larsen Hartwell, *Research Fellow*

Poverty and Livelihoods Analysis and Impact Assesment - MP5

Dr Kamel Shideed, *Director*
Dr Aden Aw-Hassan, *Agricultural Economist*
Dr Farouk Shomo, *Socioeconomist Researcher*
Dr Malika Abdelali Martini, *Socioeconomist, Community & Gender Analysis Specialist*
Dr Ahmed Mazid, *Agricultural Economist*
*Mr Markus Buerli, *Junior Professional Officer*

Knowledge Management and Dissemination for Sustainable Development - MP6

Dr Ahmed Eltigani Sidahmed, *Director*
Dr Abdul Bari Salkini, *Agricultural Economist, Liaison Scientist*
Dr Hanadi Ibrahim El-Dessougi, *Verification and Up-scaling Scientist*
Dr Catherine Farnworth, *Coordinator, CWANA Sub-Global Component of the IAASTD*

Seed Unit

*Dr Antonius Van Gastel, *Head (until April 2006)*
Dr Zewdie Bishaw, *Head (from May 2006)*
Dr Koffi Nenonene Amegbeto, *Agricultural Economist*
Mr Abdoul Aziz Niane, *Research Associate*

Geographic Information Systems Unit

Dr Eddy De Pauw, *Head*
*Mr Adekunle Gabriel Ibiyemi, *Senior GIS Analyst*

Communication, Documentation, and Information Services

Dr Surendra Varma, *Head*
*Mr James Oladipo Falaiye, *Science Writer/Editor*
Dr Nuhad Maliha, *Library & Information Services Manager*
Dr Moyomola Bolarin, *Multimedia/Training Material Specialist*
Mr Ajay Varadachary, *Communication Specialist*

Human Resources Development Unit

*Dr Samir El-Sebae Ahmed, *Head*

Computer and Biometrics Services

Dr Zaid Abdul-Hadi, *Head*
Dr Murari Singh, *Senior Biometrician*
Mr Awad Awad, *Database Administrator and Financial Systems Senior Analyst*
Mr Colin Webster, *Systems Programmer/Network Administrator*
Dr Fadil Rida, *Applications Specialist (Oracle Financials)*
Mr Hashem Abed, *Scientific Databases Specialist*
Mr Michael Sarkisian, *Senior Maintenance Engineer*

Station Operations

Dr Juergen Diekmann, *Farm Manager*
Mr Bahij El-Kawas, *Senior Supervisor - Horticulture*
*Mr Ahmed Shahbandar, *Assistant Farm Manager*

*Left during 2006

Purchasing and Supplies

Mr Essam Abd Alla Saleh Abd El-Fattah, *PSD Manager*

Visitors Section

Mr Afif Dakermanji, *Administrative Officer*

Labor Office

Mr Ali Aswad, *Consultant for Security at ICARDA*

International School of Aleppo

Mr Robert Thompson, *Head*

Damascus Office/Guesthouse, Syria

Ms Hana Sharif, *Head*

Beirut Office/Guesthouse, Lebanon

Mr Anwar Agha, *Consultant-Executive Manager*

Terbol Research Station, Lebanon

Mr Munir Sughayyar, *Terbol Station Manager*

Regional Programs

North Africa Regional Program Tunis, Tunisia

Dr Mohammed El-Mourid, *Regional Coordinator*

Arabian Peninsula Regional Program Dubai, United Arab Emirates

Dr Ahmed Tawfik Moustafa, *Regional Coordinator*
Dr Ahmed El Tayeb Osman, *Consultant (Range/Forage Specialist)*
*Dr Abdel Azim El-Hammady, *Date Palm Specialist*

West Asia Regional Program Amman, Jordan

Dr Ahmed Amri, *Regional Coordinator and Iran/ICARDA Project Leader*

Nile Valley and Red Sea Regional Program Cairo, Egypt

Dr Khaled Makkouk, *Regional Coordinator*

Highland Regional Program Tehran, Iran

Dr Ahmed Amri, *Iran/ICARDA Project Leader*
*Dr Habib Ketata, *Coordinator of the Iran/ICARDA Project*

Central Asia and the Caucasus Regional Program Tashkent, Uzbekistan

Dr Raj Paroda, *Regional Coordinator, ICARDA-CAC, and Head of Program Facilitation Unit, CGIAR Program for CAC*
Dr Mekhlis Suleimenov, *Consultant*
Dr Zakir Khalikulov, *Germplasm Scientist/Liaison Officer*

Kabul, Afghanistan

*Dr Nasrat Wassimi, *Executive Manager*
Mr Abdul Rahman Manan, *Country Manager of ICARDA Kabul Office*
Dr Syed Javed Hasan Rizvi, *Assistant Country Manager and Senior Communication Specialist*
Dr Ghulam Mohammad Bahram, *Agricultural Economist*
Mr Syed Tehseen Gilani, *Finance Officer*

Muscat, Oman

Dr Mohamed Aaouine, *Date Palm Specialist*

Islamabad, Pakistan

Dr Abdul Majid, *Officer in Charge*

Consultants

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

*Left during 2006
**Passed away in April 2006

Appendix 10 – Acronyms

AAAID Arab Authority for Agricultural Investment and Development

AARINENA Association of Agricultural Research Institutions in the Near East and North Africa

ACIAR Australian Centre for International Agricultural Research

ACSAD Arab Center for Studies of the Arid Zones and Dry Lands, Syria

ADB Asian Development Bank, Philippines

AFESD Arab Fund for Economic and Social Development, Kuwait

AGERI Agricultural Genetic Engineering Institute, Egypt

ALP Alternative Livelihood Program, Afghanistan

ALRC Arid Land Research Center

AOAD Arab Organization for Agricultural Development, Sudan

AREO Agricultural Research and Education Organization, Iran

APAARI Asia Pacific Association of Agricultural Research Institutions

APRP Arabian Peninsula Regional Program

ARS Agricultural Research Service, USDA

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

CACILM Central Asian Countries Initiative for Land Management

CACRP Central Asia and the Caucasus Regional Program

CAREERI Cold and Arid Regions Environmental and Engineering Research Institute

CAS Chinese Academy of Sciences

CGIAR Consultative Group on International Agricultural Research

CIDA Canadian International Development Agency

CIHEAM Centre International de Hautes Etudes Agronomiques Mediterraneennes, France

CIMMYT Centro Internacional de Mejoramiento de Maiz □ 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

CWANA Central and West Asia and North Africa

DARI Dryland Agricultural Research Institute, Iran

DFID Department for International Development, UK

EMBRAPA Brazilian Agricultural Research Corporation

EPMR External Program Management Review

FAO Food and Agriculture Organization of the United Nations, Italy

GAP Southeastern Anatolia Project, Turkey

GCC Gulf Cooperation Council

GCSAR General Commission for Scientific and Agricultural Research, Syria

GEF Global Environment Facility

GFAR Global Forum on Agricultural Research

GIS Geographic Information Systems

GRDC Grains Research and Development Corporation, Australia

GRI Global Rust Initiative

GTZ German Technical Cooperation Agency

IAASTD International Assessment of Agricultural Science and Technology for Development

IAS-CSIC Institute of Sustainable Agriculture, Scientific Research Council of Spain

ICARDA International Center for Agricultural Research in the Dry Areas

ICBA	International Center for Biosaline Agriculture, Dubai
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
ICT-KM	Information and Communication Technology - Knowledge Management
IDDC	International Dryland Development Commission
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
IIED	International Institute for Environment & Development
ILRI	International Livestock Research Institute, Kenya
INCO-MED	International Cooperation with Mediterranean Partner Countries (European Union)
INRA	Institut National de la Recherche Agronomique
IPGRI	International Plant Genetic Resources Institute, Italy (now Bioversity International)
IPM	Integrated Pest Management
IRDEN	Integrated Research and Durum Economics Network
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 Cooperation Agency, Japan
JIRCAS	Japan International Research Center for Agricultural Sciences
KMD	Knowledge Management and Dissemination
LARP	Latin America Regional Program
M&M	Mashreq and Maghreb
NARP	North Africa Regional Program
NARS	National Agricultural Research Systems
NCARTT	National Center for Agricultural Research and Technology Transfer, Jordan
NENA	Near East and North Africa
NGO	Non-Governmental Organization
NVRSRP	Nile Valley and Red Sea Regional Program
OFID	OPEC Fund for International Development
OPEC	Organization of Petroleum Exporting Countries, Austria
QTL	Quantitative Trait Locus
RALF	Research on Alternative Livelihood Fund, Afghanistan
RAMP	Rebuilding Agricultural Market Program, Afghanistan
SPII	Seed and Plant Improvement Institute, Iran
SDC	Swiss Agency for Development and Cooperation, Switzerland
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
UPOV	International Union for the Protection of New Varieties of Plants, Switzerland
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VBSE	Village-Based Seed Enterprise
WANA	West Asia and North Africa
WARP	West Asia Regional Program

Appendix 11 – ICARDA Addresses

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