ICARDA
Annual Report 2003







ICARDA

International Center for Agricultural Research in the Dry Areas

About ICARDA and the CGIAR

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based in Aleppo, Syria, it is one of 15 centers supported by the Consultative Group on International Agricultural Research (CGIAR).

ICARDA serves the entire developing world for the improvement of lentil, barley and faba bean; all dry-area developing countries for the improvement of on-farm water-use efficiency, rangeland, and small-ruminant production; and the Central and West Asia and North Africa region for the improvement of bread and durum wheats, chickpea, forage legumes, and farming systems. ICARDA's research provides global benefits of poverty alleviation through productivity improvements integrated with sustainable natural-resource management practices. ICARDA meets this challenge through research, training, and dissemination of information in partnership with the national agricultural research and development systems.

The results of research are transferred through ICARDA's cooperation with national and regional research institutions, with universities and ministries of agriculture, and through the technical assistance and training that the Center provides. A range of training programs is offered, from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and specialized information services.

The CGIAR is an international group of representatives of donor agencies, eminent agricultural scientists, and institutional administrators from developed and developing countries who guide and support its work. The CGIAR receives support from many country and institutional members worldwide. Since its foundation in 1971, it has brought together many of the world's leading scientists and agricultural researchers in a unique South–North partnership to reduce poverty and hunger.

The mission of the CGIAR is to promote sustainable agriculture to alleviate poverty and hunger and achieve food security in developing countries. The CGIAR conducts strategic and applied research, with its products being international public goods, and focuses its research agenda on problem-solving through interdisciplinary programs implemented by one or more of its international centers, in collaboration with a full range of partners. Such programs concentrate on increasing productivity, protecting the environment, saving biodiversity, improving policies, and contributing to the strengthening of agricultural research in developing countries.

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

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

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

Contents

Foreword

Strong partnerships with national agricultural research systems and other stakeholders constitute the backbone of ICARDA's research agenda. The outreach programs of the Center play a key role in promoting partnerships in their respective sub-regions and in implementing collaborative research and training programs. To make an assessment of the efficiency and effectiveness of the partnerships, the Board of Trustees of ICARDA commissioned an external review of its outreach programs in 2003. The distinguished Review Panel reaffirmed the success of ICARDA in enabling dry-area countries in the world to become fully involved in, and benefit from its programs. The Panel also noted that the Center is held in high esteem by national scientists, research managers, and policy makers in the Central and West Asia and North Africa (CWANA) region—ICARDA's eco-geographic mandate area.

Within the context of contributing to the Millennium Development Goals, the Center made a strong case at the World Water Forum, held in Japan, and at the International Conference on the Development of Dry Lands, held in Iran, about the urgent need to address the issue of water shortages that are threatening food security in the dry areas, and proposed actions that could lead to sustainable use of natural resources and help alleviate poverty and hunger. The Center also actively participated in the project development for Challenge Programs on "Water and Food " and "Biofortified Crops for Improved Nutrition," and three of its six projects submitted were approved for funding.

The use of cutting-edge science is becoming more crucial in addressing the daunting global challenges of producing more with less land and water to feed the increasing populations, while protecting the health of the natural resource base. During the year, ICARDA made significant strides in the use of such tools as biotechnology, geographical information systems and expert systems to develop crop varieties that can withstand stressful conditions, and technologies for improved water conservation and use efficiency.

Conflicts in the CWANA region continued to pose challenges for the Center. During the year, our work to rebuild agriculture in Afghanistan continued with increased emphasis on seed systems and capacity building, while preparations were set in motion to support rebuilding agriculture in Iraq. A collaborative work plan was developed in partnership with senior Iraqi officials and scientists. Implementation of the plan began during the later part of the year, and is expected to gain momentum in 2004. Our work in the Palestinian territories, mainly through human resource development, providing seeds of improved varieties and assisting in agrobiodiversity conservation using natural resource management practices, continued despite the prevailing difficult situation there.

In presenting this Annual Report to our readers, we would like to extend ICARDA's grateful thanks to donors for their continued support to the Center's research and training activities. We also thank our partners throughout the world for their valuable contributions to the collaborative work and achievements reported here.

Margaret Catley-Carlson
Chair, Board of Trustees

Adel El-Beltagy
Director General

In 2003, ICARDA sharpened the focus of its research and training activities on poverty alleviation and improving livelihoods in the dry areas with a view to making increased contributions to the attainment of the Millennium Development Goals, particularly those related to agriculture: eradicate extreme poverty and hunger, ensure environmental sustainability, and build a global partnership for development. As in past years, ICARDA continued to promote partnerships with national research systems (NARS) and advanced research institutes. The collaborative research led to the release of more than 29 varieties of cereal and legume crops in 15 countries of the Central and West Asia and North Africa (CWANA) region. During the year, a Center-Commisioned External Review of ICARDA's outreach activities was conducted. The Review Panel commended the Center for the successful establishment and expansion of its regional programs which cover all the countries of the CWANA region in a comprehensive manner. The panel also noted that the Center is held in high esteem among national scientists and research managers. The top policy makers are well aware of the activities carried out jointly by their countries and ICARDA. The year also saw continued active participation of the Center in global and regional initiatives related to agricultural research and development in dry areas. Efforts to rebuild agriculture in Afghanistan continued, and new initiatives were taken to support agricultural research and infrastructure development in Iraq. The work of some staff members earned honors and awards. Some of the highlights of the Center's activities are presented here; progress made in specific projects is reported in subsequent chapters.

Fostering Development of Dry Areas

During the year, ICARDA participated in and organized several meetings aimed at fostering the development of agricultural research in the dry areas.

- Two consultation workshops on rural development in the CWANA region were jointly organized by ICARDA and the World Bank in February in Cairo in February. The first workshop focused on the "World Bank Strategy for Rural Development: Reaching the Poor," and the second on the proposed "International Assessment of the Role of Agricultural Science and Technology in Reducing Hunger, Improving Rural Livelihoods, and Stimulating Economically Sustainable Growth." Drs Kevin Cleaver, Latitia Obeng, and Csaba Csaki, from the World Bank, presented the latest strategy papers. At the joint opening session of the two workshops, His Excellency Prof. Dr Youssuf Wally, Deputy Prime Minister and Minister of Agriculture and Land Reclamation, Egypt, appreciated the initiative, "which would greatly help in the rural development efforts in the region," he said. H.E. Mr Sayed Hussain Anwari, Minister of Agriculture and Livestock, Afghanistan, was among those who participated in the workshop.
- Water scarcity and its potential adverse consequences for food security in dry areas was the key

H.E. Prof. Dr Youssuf Wally *(center)*, Deputy Prime Minister and Minister of Agriculture and Land Reclamation, Egypt, inaugurated two World Bank Consultation workshops in a joint opening session in February in Cairo. Present with him were Dr Mahmoud Ayoub *(left)*, Director, World Bank Country Department, Cairo; Prof. Dr Adel El-Beltagy *(second from left)*, Director General, ICARDA; H.E. Mr Sayed Hussain Anwari *(second from right)*, Minister of Agriculture and Livestock, Afghanistan; and Dr Kevin Cleaver *(right)*, Director, Rural Development Department, the World Bank.

At the Fakhrabad site in Tajikistan, Mr Sadulla, a farmer participating in an experiment on terracing and mulching to reduce soil erosion, shows to Prof. Dr Adel El-Beltagy *(left)*, ICARDA Director General, the successful establishment of fruit tree saplings with improvised drip irrigation using plastic bottles and straw mulching. The success rate was more than 80%.

message delivered by ICARDA Director General Prof. Dr Adel El-Beltagy at the ministerial and other high-level meetings during the Third World Water Forum (WWF) in Kyoto, Japan, in March 2003. Prof. El-Beltagy called for special attention to be given to the "serious water scarcity situation in the dry areas" to safeguard the food security of the one billion people who live in these areas and ensure "the sustainability of their ecological systems." He highlighted ICARDA's role in managing this scarce resource by improving water-use efficiency for sustainable food production. The Ministerial declaration of the forum reflected the urgency of dealing with water scarcity, adoption of new policies, and the use of cutting-edge science to address the problems.

- Researchers and research administrators from 25 countries met at the Seventh International Conference on Development of Dry Lands, held in Tehran, Iran, 14-17 September, to explore how technology can help ensure sustainable development in the world's dry areas. The Conference, organized under the auspices of the International Dry Lands Development Commission (IDDC), was jointly sponsored by the Ministry of Jihad-e-Agriculture, Iran, and ICARDA. Additional support was provided by FAO (Food and Agriculture Organization of the United Nations) and COMSTEC (Committee for Scientific and Technological Cooperation). Over 217 participants made 100 oral presentations and 80 poster displays covering soil and water degradation and conservation, forage and range management, biodiversity conservation and utilization, stress physiology, biotechnology, development and transfer of new technologies for dry lands, and study and exploitation of indigenous knowledge and heritage. The Conference was inaugurated by H.E. Eng. Mahmoud Hojjati, Minister of Jihad-e-Agriculture, Iran, and Prof. Dr Adel El-Beltagy, ICARDA Director General and Chair of IDDC.
- Representatives from regional research and development organizations met at ICARDA headquarters in May to consider options for establishing a genebank to safeguard the plant genetic resources in the Arab World. Prof. El-Beltagy emphasized the importance of cooperation in genetic resources conservation, and gave a brief review of the regional genebank

The ICARDA-sponsored Workshop Panel at the Third World Water Forum. From left to right, Prof. Dr Adel El-Beltagy, ICARDA Director General; Dr Margaret Catley-Carlson, Board Chair, ICARDA; H.E. Dr Mahmoud Abu-Zeid, Minister of Irrigation and Water Resources, Egypt; Dr Ismail Seralgeldin, Director, Bibliotheca Alexandrina, Egypt; Professor Theodor Hsiao, University of California, Davis; and Professor Iwao Kobori, former Vice-Chair, ICARDA Board of Trustees, United Nations University, Japan.

Prof. Dr Adel El-Beltagy, ICARDA Director General, discussed the ongoing ICARDA-Iran collaboration with H.E. Eng. Mahmoud Hojjati *(center)*, Minister of Jihad-e-Agriculture, and Dr Ali Ahoonmanesh *(left)*, Deputy Minister for Agricultural Research and Education, Iran, during the Seventh International Conference on Development of Dry Lands, held in Tehran, Iran.

Iraqi and ICARDA scientists discussing work plans to rebuild agriculture in Iraq. Left to right: Dr Azzildeen Al Shamma, Ministry of Agriculture; Dr Adnan Adary, IPA Agricultural Research Center; Dr Naked A. Khamis, Ministry of Agriculture; Dr Kutaiba M. Hassan, Ministry of Agriculture; Dr W. Erskine, ADG (Research), ICARDA; and Dr Ali Abd El-Moneim, Acting Director, Germplasm Program, ICARDA.

Dr Michael Baum *(right)* briefing the Australian delegation on ICARDA's biotechnology research. Standing next to him is Mr Sandy Macdonald, Senator for New South Wales, National Party, and Leader of the Delegation.

initiative, which was first proposed formally about 10 years ago, after the signing of the international Convention on Biological Diversity (CBD). The convention recognized each country's sovereign right to its biological diversity, but made clear that each country has a responsibility to conserve biodiversity and share it with other countries. The regional genebank approach was proposed to raise countries' capacity to conserve biodiversity and fulfill the obligations outlined in the CBD. The United Nations Environment Programme Regional Office for West Asia (UNEP-ROWA) reinvigorated the initiative by funding a feasibility study conducted by ICARDA in 2002. UNEP-ROWA and ICARDA convened the meeting to consider three options arising from the study: (i) establish a network of existing national genebanks, (ii) establish four subregional genebanks, and (iii) set up a major, fully centralized genetic resources center to hold a duplicate set of the region's germplasm and cover all aspects of germplasm collection, conservation, and sharing.

A group discussion with farmers during a training course on seed production in Afghanistan.

Rebuilding Agriculture in Afghanistan

Within the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), led by ICARDA, the Center established three main quality control and quarantine seed testing stations and six satellite seed stations at strategic locations in the country with support from the United States Agency for International Development (USAID). The Badam Bagh station near Kabul was rehabilitated and reequipped. It will serve as Afghanistan's national seed testing and seed health laboratory. To set the facility in motion, ICARDA organized two training courses at Badam Bagh in June 2003 for newly recruited quality assurance personnel. The courses included the start-up and calibration of seed quality testing and seed health testing facilities. The participants received practical training in seed testing for quality control and seed health, working in small groups according to their back-ground and future assignments at various laboratories in the country.

Afghanistan Minister of Agriculture and Livestock H.E. Mr Sayed Hussain Anwari cuts the ribbon on the Ministry's refurbished recording studio, assisted by Dr Nasrat Wassimi *(right)*, Executive Manager of ICARDA's Kabul office on 11 September 2003.

The Consortium refurbished the audio recording studio and provided modern digital recording and editing equipment to enable the Afghan Ministry of Agriculture and Livestock (MOAL) to raise the number and quality of its radio programs for farmers. The new studio was opened with a ribbon-cutting ceremony by the Afghanistan Minister of Agriculture and Livestock, H.E. Mr Sayed Hussain Anwari, on 11 September 2003. The Agricultural Radio Project's weekly program "Sow Well, Reap Well" is now quite popular with the farmers throughout the country.

A competitive grants program on short-term, high impact projects, funded by USAID and managed by ICARDA, made significant contributions to rebuilding agriculture in Afghanistan.

Center Commissioned Review of ICARDA's Outreach Activities

During the year, a Center-Commissioned External Review

(CCER) of ICARDA's outreach activities was conducted. Issues of strategic importance including the regional coverage of the outreach activities, devolution/outsourcing, interaction with NARS, interplay between research and outreach, and information management were examined.

The Panel consisted of Dr Lukas Brader, former Director General of the International Institute of Tropical Agriculture (IITA) as Chairman; Dr Abderrazak Daaloul, Director General for Agricultural Production, Ministry of Agriculture, Tunisia; and Dr Mohammad H. Roozitalab, Deputy Head, International Scientific Research and Education Organization, Iran, and Chair of Global Forum for Agricultural Research. The Panel visited 10 countries in the region and held discussions with various stakeholders, as well as with ICARDA staff members. At the end of the review, the Panel made 10 recommendations for further strengthening ICARDA's outreach activities.

Noting that ICARDA has the most intensive and extensive collaborative research and related activities with its partners in the mandate region, the Panel commended the Center for the successful establishment and expansion of its regional programs which cover all the countries of the CWANA region in a comprehensive manner. The establishment of the regional programs has allowed the Center to adjust efficiently to new realities and to carry out research together with partners in areas of direct relevance to the countries and donors.

"The development and implementation of this well adapted and unique research management mechanism, as well as the mobilization of the necessary resources, is a good demonstration of the excellent foresight and communication and planning capabilities of ICARDA management and staff," the Panel commented.

The Panel also noted that the Center is held in high esteem among national scientists and research managers. The top policy makers are well aware of the activities carried out jointly by their countries and ICARDA.

CCER Panel Chair, Dr Lukas Brader *(fourth from left)* and Panel member, Dr Mohammad H. Roozitalab *(fifth from left)* visited the experimental farm of the Uzbek Cotton Growing Research Institute as part of the review of ICARDA's outreach activities. Dr Feiruza Khasanova briefed them about research activities on conservation tillage.

The Panel, however, expressed concern over the on-going reduction in core funding which has considerably limited the Center's control over the balance between priority research areas. In this connection a recommendation was made for ICARDA to work with national partners on modalities to utilize funds for rural development and related projects for agricultural research in the various countries.

Other recommendations focused on ICARDA's work in Latin America, activities in highland areas, information flow between the Center and outreach offices, and possibilities for expanding ICARDA's role as an honest broker in triangular arrangements between the Center, specialized research institutes, and countries in CWANA.

Promoting Strategic Partnerships

- In October, a new ICARDA liaison office at the Institut National de la Recherche Agronomique d'Algérie (INRAA) was opened to strengthen cooperation and improve communication between the Center and Algeria's national program. This followed the signing of a memorandum of understanding between Algeria's Ministry of Agriculture and ICARDA to backstop the activities of the National Plan for Agricultural and Rural Development.
- ICARDA hosted several distinguished visitors and delegations during the year. These included: a delegation of seven members of the Australian Parliament; H.E. Prof. Sami Gulcu, Minister of Agriculture and Rural Affairs, Turkey; H.E. Frank Hesske, Head of the Delegation of the European Commission in Syria;

Dr Kamel Feliachi *(left)*, INRAA Director General, and Dr Mohammed El-Mourid, Coordinator of ICARDA's North Africa Regional Program, cut the ribbon on a new ICARDA liaison office at INRAA in Algiers.

H.E. Peter Ford, Ambassador of the United Kingdom to Syria; H.E. Azusa Hayashi, Japanese Ambassador to Syria; H.E Svein Sevje, Ambassador of Norway to Syria; a delegation of members of parliament and senior agriculturalists from Iran; a senior delegation from Tottori University, Japan; and senior scientists from the Ministry of Agriculture, Iraq. These visiting delegations were briefed about the work of ICARDA. Specific details of the Center's work in relation to the respective countries and areas of future collaboration in research were reviewed.

Honors and Awards

- Dr Robert D. Havener, former ICARDA Board Chair, was awarded an honorary degree of Doctor of Public Service by Ohio State University (OSU), USA, in recognition of his outstanding contributions and services in international agriculture. Dr Havener is former Director General of the International Maize and Wheat Improvement Center in Mexico, President Emeritus of Winrock International Institute for Agricultural Development, and founding member and former senior consultant of the World Food Prize Foundation. He served as a Project Development Officer for the establishment of ICARDA and as a member of its founding board of trustees. More recently, he again served on the ICARDA Board of Trustees and as its Chair from 1999 to May 2003.

- Honorary doctorate degrees were conferred on Dr Mohan C. Saxena, Assistant Director General (At-Large) and Dr Rajendra Singh Paroda, Head of Project Facilitation Unit of the CGIAR Program for Central Asia and the Caucasus (CAC) and Regional Coordinator, ICARDA-CAC, on 14 November 2003 by the Sardar Vallabh Bhai Patel University of Agriculture and Technology, based in Meerut, Uttar Pradesh, India, on the occasion of its annual convocation. The honor recognizes the contributions of Drs Saxena and Paroda to agricultural research and development in developing countries, particularly India.
- Dr Rajendra Singh Paroda also received two other awards during the year: the prestigious Dr B.P. Pal Memorial Award and a gold medal from the National Academy of Agricultural Sciences, India, for his "singular outstanding contributions in the field of agricultural research and development in India"; and honorary professor of Samarkand State University, Uzbekistan.
- An ICARDA poster was one of the winners among the top five selected for an award at the Second Triennial Conference of the Global Forum on Agricultural Research (GFAR), held in Dakar, Senegal, 22-24 May, under the theme "Linking Research and Rural Innovation to Sustainable Development." More than 400 researchers, research administrators, farmers, members of the private sector, and donors took part. A panel of judges awarded a plaque of recognition to ICARDA for a poster entitled "Protected Agriculture in the Mountain Terraces of Yemen: More Income for Farmers from Less Water," authored by Dr Ahmed Moustafa, Coordinator of ICARDA's Arabian Peninsula Regional Program; and Abdul Wahed Mukred, Amin Al-Kirshi, Mohammad Al-Sadi, and Mohammad Al-Dhubani, all of the Agricultural Research and Extension Authority (AREA), Yemen, based on the collaborative research.

New crop varieties released in 2003

In 2003, ICARDA and its partners released several new varieties of barley, chickpea, wheat, faba bean, lentil and forages.

Barley:	'INIAP-Pacha2003' and 'INIAP-Canicapa20' in Ecuador; 'Capuchona Plus' in Mexico
Chickpea:	'Bouchra' and 'Neyer' in Tunisia; 'INCT' in Turkey, 'Elexir' in Georgia; and 'Narmin' in Azerbaijan
Durum wheat:	'Boussellam-3' in Algeria; INRA 1804, 1805, 1807, 1808, and 1809 in Morocco, and 'Nasr' in Tunisia
Faba bean:	'Farah' and 'Cairo' in Australia; S.L.L in China; 'Sakha 3' in Egypt; and 'Chahbi' in Tunisia
Lentil:	'Assano' in Ethiopia; 'Hala' in Lebanon; 'Zaria' in Morocco, 'Masoor-2002' in Pakistan; and 'Siliana,' and 'Kef' in Tunisia
Forages:	'Abigi,' 'Abika,' and 'Abiza' in Georgia

ICARDA developed a new strategy and initiated a project-based system in 1998, outlined in this chapter, of conducting and administering its research and training activities.

While detailed descriptions of all projects can be found at ICARDA's web site (www.icarda.org), the pages that follow present some key achievements made in each project during 2003.

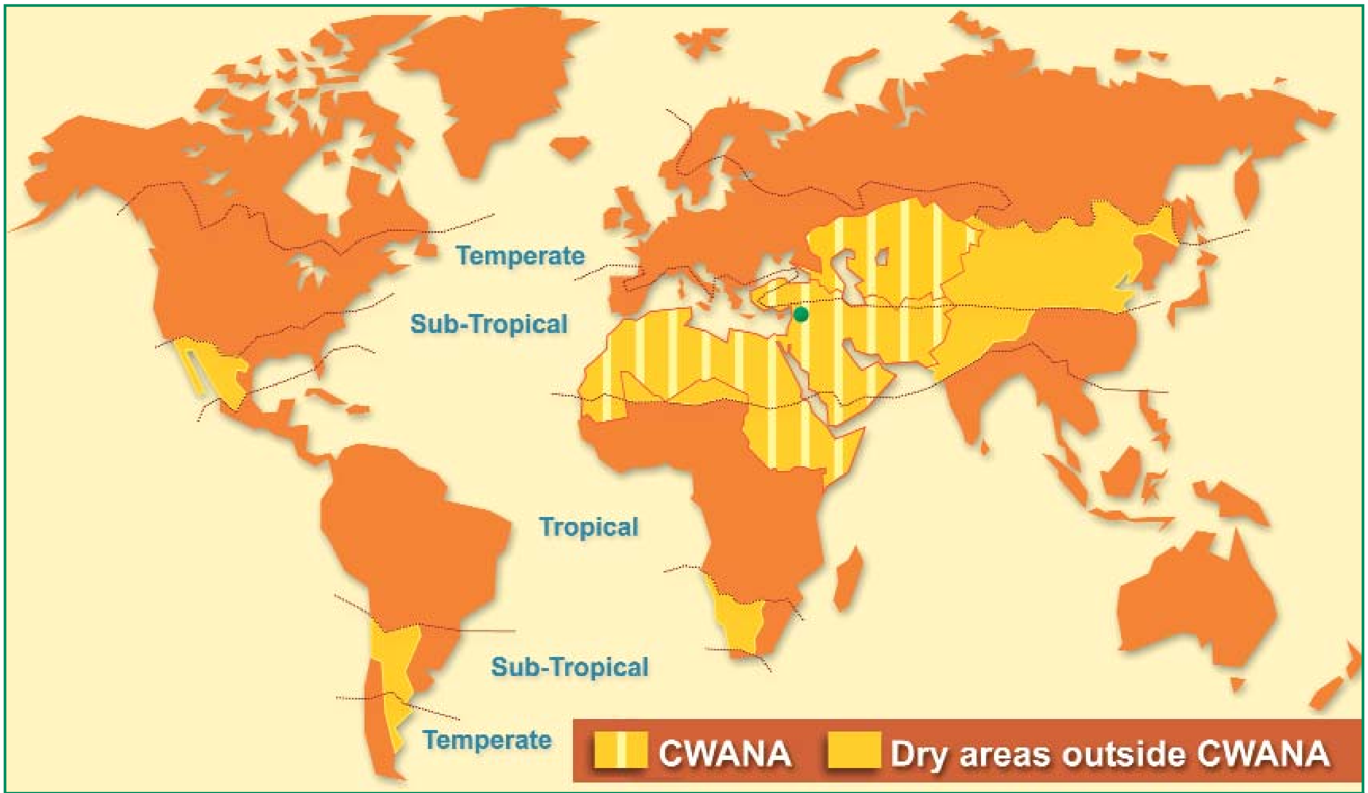
Agricultural systems in the dry areas are dynamic. Global linking of national economies and urban market development are creating new, more intensive, and more diverse demands on agricultural producers. The demographic pressure on the land combined with the need to produce more food from a limited resource base is forcing producers to follow practices that maximize short-term returns at the expense of long-term sustainability. Environmental resource degradation and human poverty are most pronounced in low-potential agricultural environments, particularly those with low and uncertain rainfall, in mountainous areas, and in the rangelands. Rural to urban, as well as international migration, is widespread, particularly in the Mediterranean region, and threatens social, political, and economic stability.

To deal with the challenges of poverty, food insecurity, and resource degradation, ICARDA's research agenda is built around five general themes:

1. Crop Germplasm Enhancement
2. Production Systems Management
3. Natural Resource Management
4. Socioeconomics and Policy
5. Institutional Strengthening

Theme 1. Crop Germplasm Enhancement

This theme includes six projects, each developed around a particular crop or group of crops. The overall goal of the projects is to steadily increase yield and stability through genetic improvement and water-use efficiency, with special emphasis on less favored environments and low external-input systems. The strategy is to produce cultivars with stable year-to-year yield adapted to the environments in which they will be grown. The projects are multidisciplinary, with research targeted to specific dry-area farming systems. As such, they integrate genetic improvement with



The eco-geographic mandate of ICARDA's research covers the countries of Central and West Asia and North Africa (CWANA), as well as other developing countries with subtropical and temperate dry areas. The term 'dry areas,' in the context of ICARDA's research program, refers to those areas where the length of the crop growing period is less than 180 days because of the limitation of rainfall.

production systems, resource management, and socioeconomic and policy considerations. ICARDA is an active partner in the CGIAR Challenge Program on "Biofortified Crops for Improved Nutrition."

The following projects are in operation under this theme:

Project 1.1. Barley Germplasm Improvement for Increased Productivity and Yield Stability

Project 1.2. Durum Wheat Germplasm Improvement for Increased Productivity, Yield Stability, and Grain Quality in West Asia and North Africa

Project 1.3. Spring Bread Wheat Germplasm Improvement for Increased Productivity, Yield Stability, and Grain Quality in West Asia and North Africa

Project 1.4. Winter and Facultative Bread Wheat Germplasm Improvement for Increased Yield and Yield Stability in Highlands and Cold Winter Areas of Central and West Asia and North Africa

Project 1.5. Food Legume (Lentil, Kabuli Chickpea, and Faba Bean) Germplasm Improvement for Increased Systems Productivity

Project 1.6. Forage Legume Germplasm Improvement for Increased Feed Production and Systems Productivity in Dry Areas

Theme 2. Production Systems Management

Production systems management draws together all the components of research into a farming systems perspective. This approach enables site-specific results to be blended into recommendations that can be applied to broader target areas. Long-term experiments on the productivity of farming systems, particularly those integrating crops and livestock, and the management of soil and water resources, are geared to optimize cropping sequences and the development of appropriate ways to intensify production in the dry areas. Optimizing soil water use is a particularly important area in which ICARDA is a co-convener with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), of the Optimizing Soil Water Use (OSWU) Program, within a "CGIAR Systemwide Soil Water and Nutrient Management (SWNM) Consortium."

Management of crop pests and diseases is increasingly handled in an integrated fashion in order to reduce the environmental and economic impact of chemical interventions. ICARDA views pest and disease management as a dimension of the entire farming system rather than as one component of the production practices for a single crop. ICARDA participates in three sub-programs of the "CGIAR Systemwide Integrated Pest Management Program."

The following projects are in operation under this theme:

Project 2.1. Integrated Pest Management in Cereal- and Legume-based Cropping Systems in Dry Areas

Project 2.2. Agronomic Management of Cropping Systems for Sustainable Production in Dry Areas

Project 2.3. Improvement of Sown Pasture and Forage Production for Livestock Feed in Dry Areas

Project 2.4. Rehabilitation and Improved Management of Native Pastures and Rangelands in Dry Areas

Project 2.5. Improvement of Small-Ruminant Production in Dry Areas

Theme 3. Natural Resource Management

ICARDA's research on natural resource management aims to promote efficient, integrated, and sustainable use of resources for improved productivity and alleviation of poverty. The Center's research plan responds to the vision expressed at the Lucerne meeting in Switzerland 9-10 February 1995 and to recommendations in TAC's 1995 report, "Priorities and Strategies for Soil and Water Aspects of Natural Resource Management Research in the CGIAR," and the Maurice Strong report on "Systemwide Review, 1999." ICARDA is an active partner in the CGIAR Challenge Program on "Water and Food." While water and its availability are the key issues in the dry areas and are accorded the highest priority, soil, agricultural biodiversity, and land use are all closely linked. ICARDA maintains a strong Genetic Resources Unit and participates in the "System-wide Genetic Resource Program."

ICARDA is responding to the urgent need for higher productivity using less water by substantially increasing its research investment on improved and sustainable water-use efficiency at the farm level. The Center leads the work in this field and contributes to the "CGIAR Systemwide Program on Water Management," coordinated by the International Water Management Institute (IWMI). In this program, on-farm water management is integrated in an overall water-basin perspective.

The following projects are in operation under this theme:

Project 3.1. Water Resource Conservation and Management for Agricultural Production in Dry Areas

Project 3.2. Land Management and Soil Conservation to Sustain Rural Livelihoods of Dry Areas

Project 3.3. Agrobiodiversity Collection and Conservation for Sustainable Production

Project 3.4. Agroecological Characterization for Agricultural

Research, Crop Management, and Development Planning

Theme 4. Socioeconomics and Policy

Socioeconomic and policy research provides gender, market, cultural and end-user perspectives that can help in promoting the adoption of new technologies and enhance the impact and benefits of ICARDA's research. Particular emphasis is placed on participatory research methods for problem identification, technology evaluation and selection that complement the formal analytical methods already in use. The strategy is to build upon the knowledge, perspectives, and innovative capacities of farmers and local communities in finding solutions to production and resource-management problems.

As part of its new strategy, ICARDA is devoting increased attention to natural resource management, especially water, formal methods of resource and environmental economics, and farmers' participatory research to understand how resource degradation, productivity, and conservation are related. Operational guidelines on resource use for farmers, pastoralists, extensionists and policy makers are being identified. Development of local institutions will be investigated and institutional innovations that mitigate natural resource degradation and enhance collective action will be promoted.

The following projects are in operation under this theme:
Project 4.1. Socioeconomics of Natural Resource Management in Dry Areas
Project 4.2. Socioeconomics of Agricultural Production Systems in Dry Areas
Project 4.3. Policy and Public Management Research in West Asia and North Africa

Theme 5. Institutional Strengthening

ICARDA has a strong program of technical assistance to National Agricultural Research Systems' (NARS) seed-production efforts. While supporting this essential activity, the Center emphasizes the needs of the informal seed sector to stimulate improvements that are not adequately met by existing services. These include partnerships with government agencies, farming communities and NGOs, and opening up the possibility of new initiatives by the private sector.

The following project is in operation under this theme:
Project 5.1. Strengthening National Seed Systems in Central and West Asia and North Africa

Training

Training is an integral part of ICARDA's research projects. The Center's research partnerships with NARS are strengthened implicitly by colleague-to-colleague training. Increasingly, the Center is out-sourcing its training activities to make the best use of the expertise that is becoming more readily available in NARS. Training focuses on improved quality and effectiveness, and on achieving multiplier effects through training the NARS trainers. ICARDA encourages greater participation of women scientists from NARS in its training programs.

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.

Key Features of ICARDA's Research Stations

ICARDA sites in Syria and Lebanon

Sites	Coordinates		Approx elevation (m)	Area (ha)	Total precipitation (mm) *	Long-term average (mm)
	Latitude	Longitude				
SYRIA						
Tel Hadya	36.01° N	36.56° E	284	948	400.2	351.1 (26 seasons)
Breda	35.56° N	37.10° E	300	95	303.4	274.5 (24 seasons)
LEBANON						
Terbol	33.49° N	35.59° E	890	23	549.8	537.5 (24 seasons)
Kfardane	34.01° N	36.03° E	1080	11	539.0	462.6 (10 seasons)

* For the 2002/03 season

Project 1.1. Barley Germplasm Improvement for Increased Productivity and Yield Stability

Barley, *Hordeum vulgare* L., was probably the first cereal crop cultivated for human consumption in the Fertile Crescent thousands of years ago. Archaeological evidence suggests that, in the past, barley was more popular than wheat in North Africa. Today, barley is widely grown for animal feed, and for making malt. However, it is still an important staple food for many of the world's poor living in regions of high altitude and low rainfall.

In 2003, research to improve the productivity and yield stability of barley germplasm progressed further, as ICARDA researchers mapped quantitative trait loci (QTLs) for various useful agronomic traits in a wild × cultivated barley cross. This will make future selection of improved barley lines more efficient. In Jordan, a barley breeding program involving the active participation of both female and male farmers and breeders was very successful. As a result, the national institution involved adopted the participatory approach to breeding and, at the request of farmers, extended it to other major crops.

The first-ever comparison of the costs of conventional and participatory plant breeding (PPB) was also undertaken, showing that PPB is more flexible than the non-participatory equivalent, while not necessarily being more costly. Advances were also made in breeding barley resistant to fusarium head blight, in collaboration with CIMMYT and the public- and private-sector institutions.

New QTLs for important agronomic traits

Hordeum spontaneum, the wild progenitor of cultivated barley, shows variation for many important agronomic traits and can contribute useful genes for barley breeding. ICARDA has been working to exploit this vast store of genetic resources through its barley breeding program since 1985.

Drought usually reduces plant height in barley. So, in some dry years, the crop is too short to be harvested mechanically—farmers either have to leave it unharvested (for grazing) or harvest it by hand at a much higher cost. One of *H. spontaneum*'s most valuable traits is its ability to grow to acceptable heights under drought. ICARDA researchers are introducing this trait in cultivated varieties of barley. In environments where both straw and grain are valuable to the farmer, tall plants under drought can ensure a high biological yield.

Evaluation of recombinant inbred lines from crosses with wild barley at Breda, a dry site in Syria.

Although *H. spontaneum* and *H. vulgare* can be crossed easily and the progenies produced are fully fertile, the introgression of *H. spontaneum* genes for plant height under drought into cultivated barley has been a long and difficult process. This is because *H. spontaneum* also has a number of undesirable traits, such as brittle rachis, low kernel weight, and rough awns that are often introduced along with the desired characteristics. Furthermore, improvements in plant height under drought often cause a reduction in the amount of grain-carrying tillers produced, which reduces both grain and straw yield.

To fully exploit the potential of crosses between cultivated barley and *H. spontaneum*, a large number of recombinant lines derived from each cross have to be evaluated. The use of quantitative trait loci (QTL) analysis and molecular markers can considerably speed up this process. QTL analysis allows researchers to find genes responsible for positive and negative agronomic traits on chromosomes. Molecular markers flagging these traits can then be used to make linkage maps. Using statistical techniques the phenotypic effects of QTLs can be estimated and marker-assisted selection performed.

To combine the greater plant height and adaptation to severe drought-stress conditions found in *H. spontaneum* 41-1 with the grain yield and tillering ability of 'Arta' (a Syrian landrace line), ICARDA crossed the two lines. The progeny were advanced by single seed descent to the F_7 generation, to produce a population of 494 recombinant inbred lines (RILs). These, and the two parent lines, were grown under rainfed conditions at ICARDA's research stations at Tel Hadya and Breda, in 1997 and 1998, giving a total of four 'year × location environments.'

A genetic linkage map containing 189 marker loci was developed for this population. For the QTL analysis, a reduced map was also constructed (Fig. 1). This contained 129 marker loci: 1 morphological marker locus (*btr* = brittle rachis), 106 amplified fragment length polymorphism (AFLP) loci and 22 simple sequence repeat (SSR) loci, allowing researchers to identify a number of QTLs associated with important agronomic traits. Specifically, scientists identified 10 QTLs for biological yield, 6 for grain yield, 21 for 1000-kernel weight, 4 for tiller number, 7 for plant height, 3 for growth habit, 1 for growth vigor, and 8 for cold damage.

In nine of the ten QTLs detected for biological yield, cultivar 'Arta' was found to have contributed the allele for high yield. 'Arta' also contributed alleles for high biological and grain yields in QTLs detected on chromosome 1H at position 5 (1H-5; Fig. 1) at Breda in both years (Table 1). Because these particular QTLs were not found in Tel Hadya, and because Breda is the drier site, these QTLs may have important consequences for yield in dryland environments. In contrast, in seven of the 21 QTLs identified for 1000-kernel weight, the allele for heavier kernels originated from *H. spontaneum*. A major QTL for 1000-kernel weight was identified at position 2H-5. This may coincide with grain-yield QTLs and other traits, mapped by other researchers, at the *vrs* locus on chromosome 2H.

All four of the QTLs for tiller number were detected at Breda in 1997. The most important of these was the QTL mapped as proximal to the *btr* locus on chromosome 3H, which explained 49% of the phenotypic variance observed (Table 1). In this case, the allele for higher tillering originated from 'Arta.' In the case of the seven QTLs detected for plant height, however, the allele for taller plants always originated from *H. spontaneum*. One of these QTLs (at 3H-4) was detected both in Breda in 1997 and 1998 and in Tel Hadya in 1997 (the three 'environments' in which plant height was measured). However, the effect demonstrated was much stronger at Breda, the drier site. Scientists were able to pinpoint this major QTL for plant height as proximal to the Bmag0013 SSR marker. It is, therefore, probably positioned at the *sdw1* locus (or *denso* locus), a dwarfing gene with commercial significance in barley breeding. The *H. spontaneum* allele at this position

Table 1. Position, statistics, and effects of major QTLs, and phenotypic variance accounted for by them, in a wild cultivated barley cross (*Hordeum spontaneum* 41-1 × 'Arta').

Position[1]	Trait[2]	Environment[3]	LOD/K[4]	Effect[5]		Var_{expl} [6]
1H-2: 53 (C.I.: 45-56)	GrH	Th97	27.4	0.65	[Hs]	10.2 %
1H-4: 100 (C.I.: 81-109)	GrH	Th97	*15.9*	0.49	[Hs]	7.0 %
1H-5: 120 (C.I.: 115-123)	GY	Br98	3.6	91	[Ar]	5.5 %
	BY	Br98	4.0	220	[Ar]	7.6 %
2H-2: 12 (C.I.: 9-16)	DH	Th97	6.7	1.9	[Hs]	8.5 %
2H-5: 63 (C.I.: 58-62)	KW	Br97	10.7	2.52	[Ar]	24.3 %
3H-1: 0 (C.I.: 0-3)	GY	Th97	76.7	2545	[Ar]	84.8 %
	BY	Th97	54.9	3284	[Ar]	72.6 %
3H-2: 16 (C.I.: 13-21)	TN	Br97	5.1	49.3	[Ar]	49.3 %
3H-4: 77 (C.I.: 71-83)	PH	Br98	16.7	7.4	[Hs]	29.1 %
	DH	Th97	9.8	3.14	[Ar]	20.0 %
	GYnb	Th97	4.1	457	[Ar]	12.8 %
3H-5: 85 (C.I.: 80-90)	KW	Th97	5.9	1.30	[Ar]	10.5 %
4H-2: 52 (C.I.: 43-59)	KWnb	Th98	5.1	2.94	[Ar]	25.3 %
5H-2: 52 (C.I.: 48-69)	CD	Th97	*53.3*	0.72	[Hs]	8.4 %
5H-4: 84 (C.I.: 76-95)	CD	Th98	*44.6*	0.26	[Hs]	11.4 %
6H-4: 78 (C.I.: 75-83)	GrH	Th97	*23.4*	0.61	[Ar]	17.8 %
	GrV	Th98	*14.9*	0.29	[Ar]	12.4 %
7H-3: 56 (C.I.: 45-73)	DH	Br97	9.4	3.66	[Ar]	35.7 %

[1] Position: The number connected to the chromosome is the number indicated in Fig. 1.

[2] GrH=Growth habit, GrV=Growth vigour, CD=Cold damage, DH=Days from emergence to heading, PH=Plant height, TN=Tillers per m2, GY=Grain yield, GYnb=Grain yield of non-brittle lines, BY=Biological yield, KW=1000 kernel weight, KWnb=1000 kernel weight of non-brittle lines.

[3] Environment: Th97=Tel Hadya 1997, Th98=Tel Hadya 1998, Br97=Breda 1997, Br98=Breda 1998

[4] LOD/K: For the case of MQM analysis, the LOD-score is given, for the case of non-parametric analysis, the K-value from the Kruskal-Wallis ANOVA (K-value *italics* in the table).

[5] Effect: Difference between the genotype with 2 alleles from one parent and the genotype with 2 alleles from the other parent (in parenthesis: the parent with the positive value trait expression, [Ar]='Arta,' [Hs]=*Hordeum spontaneum*).

[6] Var_{expl}: Phenotypic variance explained by the trait.

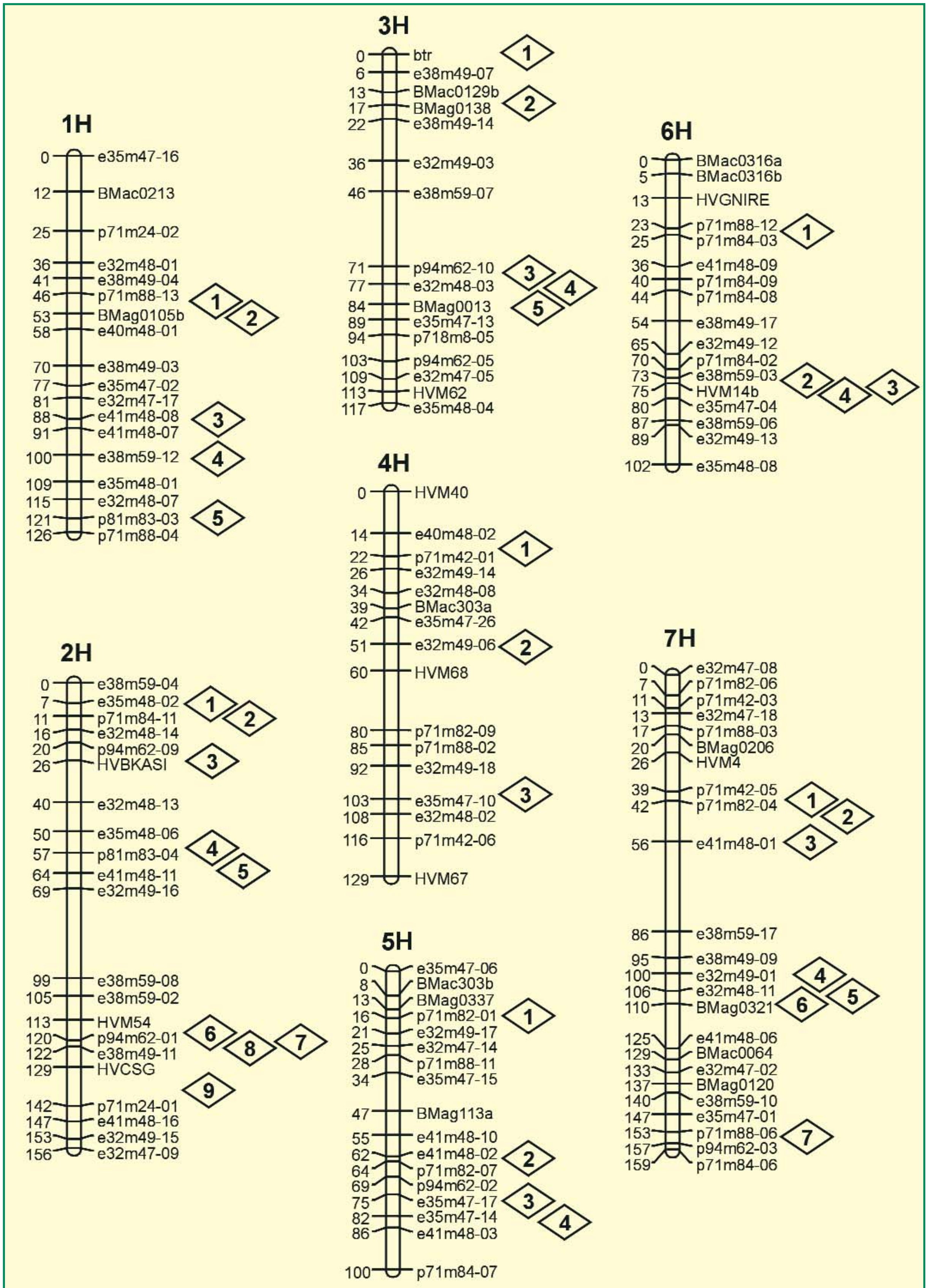


Fig. 1. Linkage map of the cross 'Arta' x *H. spontaneum* 41-1 with positions of the QTLs on the left of the chromosomes.

increases plant height under drought-stress conditions.

A prostrate growth habit is desirable in dry environments because it results in good ground cover in winter, thereby reducing evaporative water loss from the soil. Researchers found three QTLs associated with growth habit. These were detected only at Tel Hadya. One of the QTLs was found only in 1997; the other two were found in both years, but their largest effect occurred in 1997. At two of the QTLs, the allele from *H. spontaneum* was responsible for the more prostrate growth type. However, the strongest prostrate-growth effect (found at 6H-4) was caused by the 'Arta' allele.

Interestingly, a QTL for growth vigor was found at the same position on chromosome 6H as the QTL for growth habit, with the allele for more vigorous growth derived from 'Arta.' This is important because early growth vigor which describes the ability to grow at low temperatures is positively correlated with water-use efficiency and dry-matter accumulation before flowering. It is, therefore, considered to be a beneficial trait in Mediterranean-type drought-prone environments.

In addition, eight QTLs associated with cold tolerance were detected. The allele from the *H. spontaneum* line conferred better protection only to those QTLs with minor effects. For all other QTLs, better protection from cold damage was conferred by the allele from 'Arta.' Three of the four alleles which greatly increased tolerance to cold were localized on chromosome 5H (Table 1).

Lines containing plant height alleles from *H. spontaneum* and useful traits from 'Arta' may tolerate drought better under rainfed conditions than germplasm currently available. Although the study found no strong positive correlations between plant height and grain yield, a number of tall, non-brittle lines that produced high yields under stress were identified. In Breda, over the two years of the study, the 10 highest yielding lines of the population outyielded both parental lines, producing an average grain yield of 1634 kg/ha (in comparison with the means of 976 kg/ha and 1186 kg/ha produced by *H. spontaneum* 41-1 and 'Arta,' respectively). However, mean plant height was intermediate (48.3 cm) in comparison with those of the parental lines (52.4 cm and 29.0 cm for *H. spontaneum* 41-1 and 'Arta,' respectively).

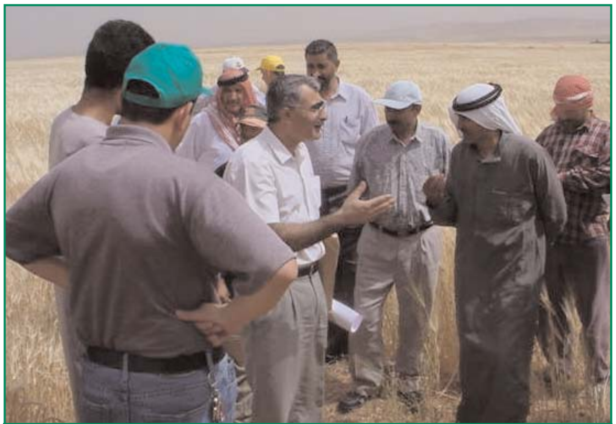
From formal to participatory plant breeding in Jordan

ICARDA is helping to improve the welfare of resource-poor, small-scale farmers in Jordan through a project that aims to increase and stabilize barley and animal production in rainfed areas. Supported by Canada's International Development Research Centre (IDRC), and building on lessons learnt from previous ICARDA-led projects, the project was able to decentralize the barley breeding program run by Jordan's National Center for Agricultural Research and Technology Transfer (NCARTT).

Researchers initially assessed the potential for increased farmer participation using a questionnaire-based survey. Then meetings were held with local farming communities, the chairpersons of local societies, and Department of Agriculture representatives to select farmers interested in participating in the project. The selected farmers then participated in three years of on-farm yield testing. The data collected were analyzed using various statistical tools (some developed by the project). Spatial analyses used the residual maximum likelihood approach, while similarities in the results of selection between various participants were assessed using Euclidean distance analysis (for quantitative data) and the genotype × environment (G×E) biplot technique. A benefits-analysis flow chart was also used, to determine how different barley by-products were used.

Planning meetings were held regularly throughout the project's timeframe. Meetings between scientists and farmers allowed the results of trials to be assessed jointly before trials for the following cropping season were planned.

Performance of some of the barley lines identified by Jordanian farmers in collaboration with national researchers involved with the participatory barley breeding project.



Farmers in Ramtha, Jordan discuss the results of their selection of barley lines with a national program researcher.

The results of the on-farm trials were as important as the benefits gained through restructuring NCARTT's breeding program (Fig. 2). NCARTT has decided to continue the participatory breeding approach introduced by the project, and institutionalize it and extend it to include two other strategically important crops: durum wheat and bread wheat.

Results from the on-farm trials led to the joint identification of nine barley lines that consistently outyielded the cultivar 'Rum.' Two of these will be submitted for official release and large-scale seed production and distribution. The project also showed that genotype × location effects were large (explaining 70-80% variation in standardized data), thus justifying the use of a decentralized breeding strategy based on selection for specific adaptation. Some of the interaction effects were repeatable across years, allowing target environments to be defined more precisely. Furthermore, breeding lines capable of producing an economic yield with only 140 mm rainfall were identified in the driest of the three years.

The participatory barley breeding approach of the project benefited both the farmers (male and female) and breeders involved, as well as NCARTT's researchers, who stated that the new approach allowed them to develop relevant technologies more quickly and to conduct innovative research.

Researchers also noted that the farmers involved had a more positive attitude towards participatory plant breeding (PPB) than in previous, non-participatory trials. Farmers were more motivated to participate in this project because they were able to select new barley varieties that suited their particular needs. As their level of participation increased throughout the project, they learnt many new skills, including identifying superior lines. They decided which type of germplasm to use and additional variables to add to the trials. They also asked to see the results of the statistical analyses undertaken and suggested crosses between entries with desirable but different traits.

Farmers felt that they were partners in research and that the scientists involved were learning from them, as well as sharing knowledge with them. As a consequence, farmers are now much more receptive to, and have more confidence in, the new technologies generated with their participation.

The project, which was one of the first in the region to actively involve female farmers in the selection process, also demonstrated that there were no serious obstacles to the participation of women, as long as researchers make a concerted effort to involve them. Female researchers are, therefore, essential to this kind of participatory project. Including female farmers in the selection process produced some very important results (Fig. 3), and it was found that the differences between the preferences of male and female farmers were greater than those between male farmers and breeders. Taking into account the views of all

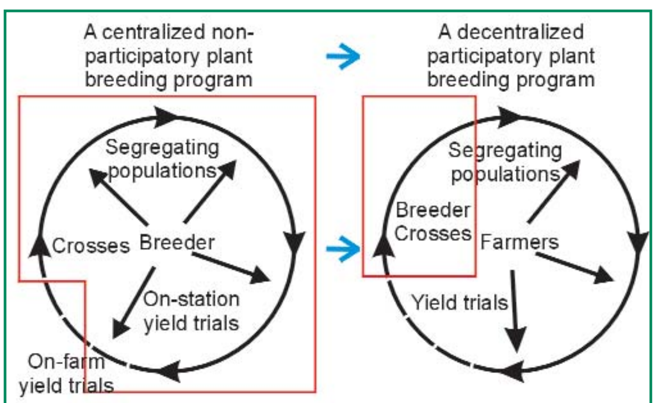


Fig. 2. The project transformed a centralized, non-participatory plant breeding program *(left)* into a decentralized participatory plant breeding program *(right)* in Jordan.

ICARDA gender specialist *(third from left)* obtains feedback from women farmers who participated in field selection at Rabba in Jordan.

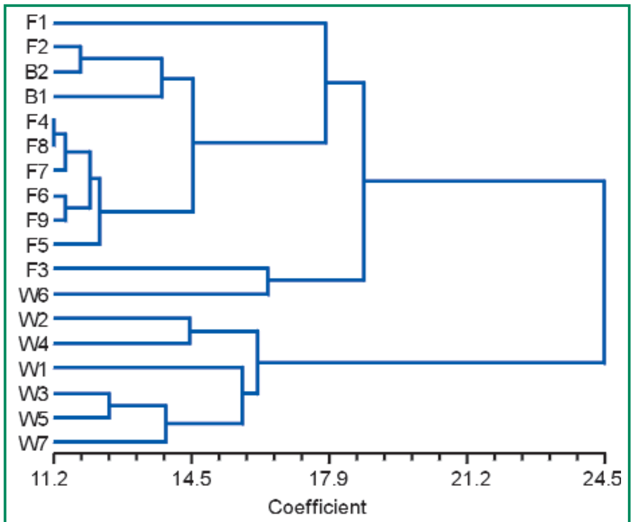


Fig. 3. Dendrogram based on cluster analysis of selections made by nine male farmers (F1 to F9), two male breeders (B1 and B2) and seven women farmers (W1 to W7) in Rabba, Syria.

participants eventually led to a strong, but not exclusive, preference for two-rowed types, and an almost unanimous rejection of black-seeded types.

The exchange of ideas promoted by the project increased breeders' confidence in local indigenous knowledge. Breeders also learned valuable lessons about the criteria that farmers use when choosing germplasm suited to their needs and their environment.

The cost of participatory plant breeding

Working with the *Istituto Agronomico per l'Oltremare* (Firenze) and the University of Tuscia (Viterbo), Italy, and with financial support from the Government of Italy, ICARDA conducted the first comparison of the costs of centralized non-participatory and decentralized participatory plant breeding (Fig. 4).

The study aimed to contribute hard data about the cost-effectiveness of decentralized participatory research for marginal environments and poor farmers—a much-debated issue in the scientific and donor communities. Plant breeding was focused upon because it is an area of agricultural research that requires large investments of human and financial resources, at both national and international levels.

The barley breeding program at ICARDA offered a good opportunity to compare the costs of the two approches to breeding, because it had adopted decentralized participatory selection in several countries in WANA. The cost-analysis study focused on Syria, where ICARDA has been successfully implementing this strategy since 1996.

The impact of ICARDA's barley breeding program is currently being assessed, and there is mounting evidence that the decentralized, participatory breeding strategy has substantially benefited both researchers and farmers. However, there were no clear indications as to whether the costs associated with the centralized program and the decentralized participatory program were different. To test the hypothesis that the costs were the same, researchers analyzed the costs incurred in one complete breeding cycle in each type of program, including those associated with the identification of parental lines, the crossing program, the production of the F_1 generation and segregating populations, and yield trials. The centralized program involves several years of on-station selection work followed by three years of on-farm testing, while the decentralized participatory program consists entirely of three years of on-farm selection and testing.

The cost analysis focused on three main components of the two programs: (i) agronomic operations; (ii) staff travel to off-station trials, as well as between stations in the centralized program; and (iii) labor costs for breeding activities and post-harvest operations. Two approaches were developed for the comparative analysis: one involving actual costs and the other involving the modeling of different cost scenarios.

In the first approach, researchers compared the actual costs (based on current ICARDA breeding activities) of each of the three components of both programs. However, because the participatory program used two

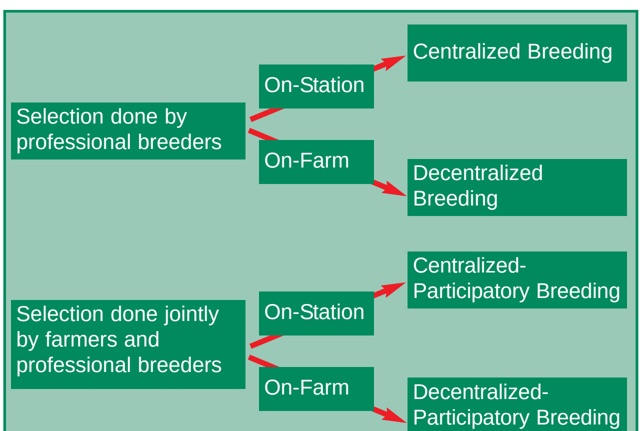


Fig. 4. Participatory plant breeding differs from non-participatory plant breeding because the selection and other operations are done jointly by the breeder(s) and the farmer(s). Both non-participatory and participatory plant breeding can be centralized or decentralized depending on where the selection is conducted.

slightly different methodologies in the field, the analysis of that program had to consider both. These were defined by the size of the trials in farmers' fields and the management responsibilities given to breeders and farmers. Under Option 1, research staff planted and harvested the 'farmer initial trials' (FIT), 'farmer advanced trials' (FAT), and 'farmer elite trials' (FET), using ICARDA's machinery, while farmers were responsible for land preparation, fertilization, weed control, etc. In contrast, under Option 2, the FET were managed entirely by farmers, while FIT and FAT were managed as in Option 1. In this case, however, the plots used in the FAT were 54 m^2 (three times larger than in Option 1).

In the second approach, researchers analyzed the variation in costs under different breeding scenarios. Again, the three main cost components of the breeding programs were considered. Two scenarios were compared for the centralized programs, one involving on-farm trials at eight sites ('CY'), and the other involving on-farm trials at 16 sites ('CT'). For the participatory program, 80 different scenarios were compared. Each differed in both the number of selection sites and the number of participating farmers at each site.

A participatory approach might be expected to affect costs because it changes agronomic operations, moving the focus of the activities away from the research station to farmers' fields. Despite this, however, it was found that the total costs of agronomic operations did not change significantly. This is because trials at the research station use only experimental machinery, which is cheaper to run, while trials in farmers' fields make use of commercial machinery. However, the savings were offset by the higher costs associated with using small plots in the centralized program.

Results showed that overall travel costs in the participatory program were lower than those in the centralized program. This was also true for most of the 80 site-by-farmer cost scenarios modeled, because the participatory program does not require the three extra years of yield testing that are an integral component of the centralized program. It was also found that participatory programs do not increase the demand for breeder services, though the demand for the services of unskilled workers and national research assistants does increase significantly. However, one of the key advantages of the participatory program is its level of flexibility. Labor costs can be reduced, if necessary, by changing the number of selection sites and of farmers per site. Or, without changing overall labor costs, the breeding scheme can be modified by changing the ratio of site and farmer numbers.

Ultimately, in both programs, agronomic operations were found to account for the largest proportion of the total breeding costs, followed by labor and travel costs (Figs. 5 and 6). The aggregated costs of the participatory program currently run at ICARDA were found to be similar to those of the centralized program, ranging between 6% less and 7% more expensive than the centralized program. The aggregated costs of the participatory breeding program were lower than those of the centralized program ('CT') in 56% of the cases analyzed in Option 2, and in 73% of the cases analyzed in Option 1 (Figs. 7 and 8).

Thus, implementing a participatory program does not necessarily imply higher breeding costs throughout the entire cycle of selection. The costs for agronomic operations, travel, and breeding activities can be maintained within the available budget by changing the number of sites, or the number

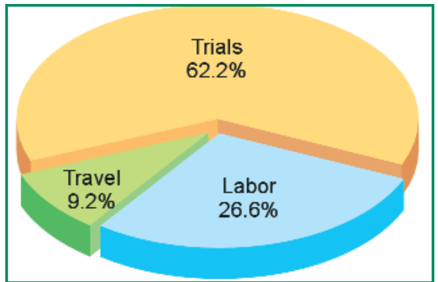


Fig. 5. Disaggregated costs of Participatory Barley Breeding Program (Option 1).

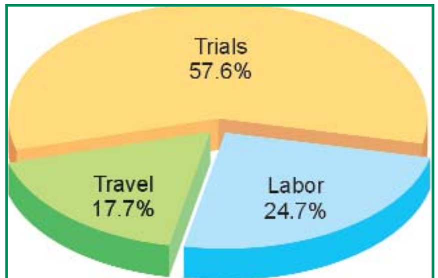


Fig. 6. Disaggregated costs of Centralized Barley Breeding Program ('CN').

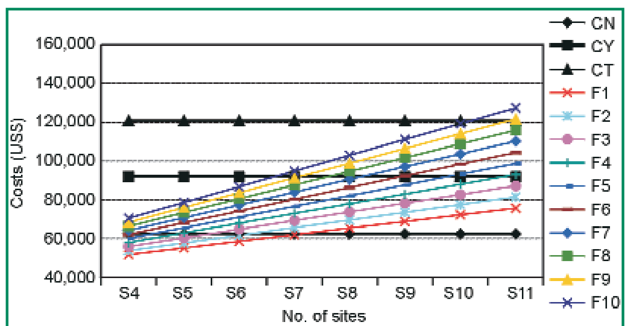


Fig. 7. Aggregated cost of Decentralized Participatory Plant Breeding (Option 1) compared with three types of Centralized Non-Participatory Plant breeding: CN = Centralized trials without on-farm trials; CY= Centralized trials including only ICARDA- managed on-farm trials (8 sites x 1 farmer); CT= Centralized on-farm trials managed by ICARDA, ACSAD, GCSAR (16 sites x 1 farmer). F1-F10 = Number of farmers per site of selection; S4-S11 = Number of selection sites.

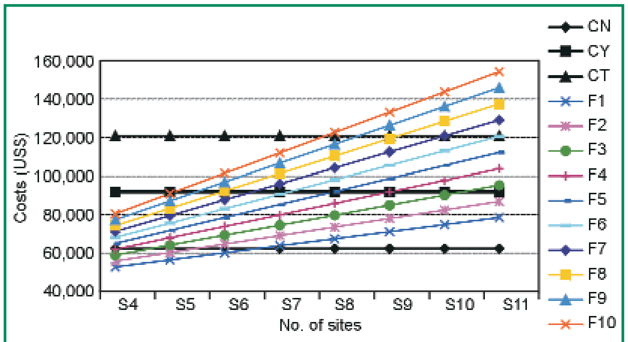


Fig. 8. Aggregated cost of Decentralized Participatory Plant Breeding (Option 2) compared with three types of Centralized Non-Participatory Plant breeding: CN = Centralized trials without on-farm trials; CY= Centralized trials including only ICARDA- managed on-farm trials (8 sites x 1 farmer); CT= Centralized on-farm trials managed by ICARDA, ACSAD, GCSAR (16 sites x 1 farmer); F1-F10 = Number of farmers per site of selection; S4-S11 = Number of selection sites.

of trials managed by farmers at each site. Although the three cost variables analyzed in this study are the most important in capturing the differences between the two approches, further work is planned. This will consider the other components involved in breeding programs, such as overheads and capital costs.

Feed, food, and malt: developing barley resistant to *Fusarium* head blight

Fusarium head blight (FHB), or scab, is a fungal disease of barley caused by several species of *Fusarium,* mainly *F. graminearum*. The disease reduces yield and grain quality by shriveling and discoloring the grain, and produces toxins harmful to people and animals. The blight is endemic in the Andean countries, southern China and the U.S., and is becoming more important in several other areas, including Argentina, southern Brazil, and Uruguay.

***Fusarium* head blight (FHB) inoculation nursery in Toluca, Mexico.**

Maize is another important host of *Fusarium* spp., and the expansion of maize production into higher latitudes (where barley cultivation is also important) has compounded the problem.

The costs of FHB damage run in millions. For example, since 1993, epidemics of the disease have caused losses of more than US$ 750 million in the USA's barley sector alone—mainly because grain intended for malting and/or feed had to be rejected.

Inoculation of barley for evaluating Type II resistance to *Fusarium* head blight (FHB) using the cotton method.

Successful partnerships enhance breeding for Fusarium resistance and high yields

Working in partnership with CIMMYT, ICARDA began to address the problem of FHB in the mid-1980s. The program tested 5000 barley lines, and found 23 that were suitable for use as a basis for resistance. Building on this, the ICARDA/CIMMYT barley program developed and distributed high-yielding resistant germplasm with acceptable agronomic characteristics to national programs. One success story was the FHB-resistant two-row variety 'Gobernadora,' which was selected in Shanghai from Mexican germplasm. Released in the early 1990s in China as 'Zhenmai-1,' this cultivar was being grown on more than 100,000 hectares by 1996 in three Chinese provinces in the lower basin of the Yangtze River.

The joint program made further progress when it identified two types of resistance that had previously been described only in wheat: Type I (resistance to fungus penetration) and Type II (resistance to the spread of the fungus in the spike). Sources of both types of resistance were crossed to produce breeding lines with combined resistance to FHB and other barley diseases. These lines were then tested at the Toluca Experimental Station, Mexico, where environmental conditions favor FHB development and its evaluation. Data were also gathered from Brazil, Canada, China, Ecuador, Uruguay, and USA, through collaboration with other institutions and companies.

In partnership with Oregon State University, 'Gobernadora' was crossed with 'Azafrán,' another Mexican variety, to produce a doubled-haploid population for molecular mapping. QTLs were identified for Type II resistance on chromosome 2, after testing the resulting lines in Mexico, China and the USA. The genes for lateral florets and anther extrusion were mapped in the same region, and lateral floret presence was found to be correlated with Type II resistance. This allows easy, indirect selection for FHB resistance to be carried out in the field since selecting for the presence of lateral florets results in selecting for FHB resistance.

Additional sources of resistance, such as 'Atahualpa' and 'Shyri' (released in Ecuador), were identified and distributed to national programs following epidemics which occurred after 1993 in the USA. Researchers used germplasm native to China to combine high yield and FHB resistance; this is likely to produce 'spin-offs' which will be valuable not only in China, but also in FHB-affected regions of Africa and Latin America.

Following the Fourth External Program and Management Review (EPMR) of ICARDA, held in 1999/2000, the scope of the ICARDA/CIMMYT barley project was expanded to include breeding for malt barley improvement. New sources of malting quality from Australia, Europe, South America, and USA were incorporated into the main crossing block, to enhance the program's contribution to Latin America, as well as to capture opportunities for worldwide collaboration.

This led to a special research project, involving collaboration with Busch Agricultural Resources Inc., (BARI Inc.), USA, which was given the highest priority by the program, because it offered a unique opportunity to develop FHB-resistant germplasm using commercial sources of malting quality barley from the USA. Begun in 2000, the project has already produced agronomically acceptable F_8 advanced lines with higher levels of FHB resistance, as well as enhanced resistance to barley stripe, stem and leaf rust, scald, net and spot blotch, and *Barley yellow dwarf virus* (Table 2). It is hoped that future testing will identify genotypes with acceptable malting quality.

Resistance to different *Fusarium* species

In 2000 and 2003, 14 *Fusarium* species were found in the main commercial barley-growing areas of the Mexican Highlands. Of these, *F. avenaceum* was the most frequent (25.5-32.0% of the fields sampled), followed by *F. graminearum* (20.0-23.5%). Several of the pathogenic species collected produced toxins when the most frequently planted cultivar was inoculated with them. Researchers also artificially inoculated genotypes from different programs in the USA, Mexico, and Latin America, to evaluate them for Type I and Type II resistance to *F. graminearum* and *F. avenaceum.* Genotypic resistance was found, with different genotypes being resistant to different species of *Fusarium*. These preliminary results suggest that any cultivars released in the Mexican Highlands should have specific resistance to *F. avenaceum*.

Collaboration with the US Wheat and Barley Scab Initiative

Formal collaboration with the United States Wheat and Barley Scab Initiative (USWBSI) began in 2000 with the delivery of putatively resistant germplasm from the ICARDA/CIMMYT program to participating programs at US and Canadian universities. This

Table 2. Results of evaluations of *Fusarium* Head Blight (FHB) resistance conducted in Toluca, Mexico, in 2003: populations derived from the ICARDA/CIMMYT/BARI Inc. special program.

Population	Cross	No. of lines	FHB (Type I %) Min	Mean	Max
1	LEGACY/4/TOCTE//GOB/HUMAI10/3/ATAH92/ALELI	110	0.13	3.34	16.93
2	LEGACY//PENCO/CHEVRON-BAR	130	0.26	2.82	8.48
3	LEGACY/3/SVANHALS-BAR/MSEL//AZAF/GOB24DH	110	0.64	5.01	14.56
4	LEGACY/5/ATACO/BERMEJO//HIGO/3/CLN-B/80.5138// GLORIA-BAR/COPAL/4/CHEVRON-BAR	80	1.04	4.23	12.46
5	LEGACY/CHAMICO	210	0.00	3.25	11.24
6	MERIT,B//CANELA/ZHEDAR#2	40	1.29	4.77	8.84
7	MERIT,B/4/GOB/HUMAI10//CANELA/3/ALELI	30	1.97	5.82	10.64
8	6B89.2027/4/TOCTE//GOB/HUMAI10/3/ATAH92/ALELI	10	5.47	10.28	17.93
9	6B89.2027/CHAMICO	50	0.00	3.33	13.07
Total		770			

Team of researchers and growers from the US Wheat and Barley Scab Initiative (USWBSI) visiting *Fusarium* head blight (FHB) experiments in Toluca, Mexico, 2002.

collaboration built upon prior informal collaboration between the ICARDA/CIMMYT program and barley programs in the US and Canada, which was initiated after a serious FHB outbreak in the American Midwest in 1993. At that time, all the germplasm previously tested by ICARDA and CIMMYT was made available to the US and Canadian programs.

Since 2000, more than 500 genotypes previously evaluated by ICARDA and CIMMYT have been sent to the US programs. A significant number of elite lines and cultivars have also been distributed by the ICARDA/CIMMYT program in Latin America and worldwide. These have been extensively used to introgress the FHB resistance developed in Mexico. The special breeding program involving ICARDA, CIMMYT, and the USWBSI makes it more likely that FHB-resistant lines will be found that are adapted to different target areas and that have a high malting quality.

The project's breeding approach has proved to be effective in different environments, as illustrated by the resistance to FHB and the low levels of deoxy-nivalenol (DON) toxin found in lines tested recently in Canada and China. Molecular studies are planned for the near future to elucidate the real level of genetic diversity present for FHB resistance in the different sources.

Project 1.2. Durum Wheat Germplasm Improvement for Increased Productivity, Yield Stability, and Grain Quality in West Asia and North Africa

Over the years, ICARDA has made steady progress in breeding durum wheat for increased productivity, yield stability, and grain quality. Using genetic mapping, genomic regions that contribute to tolerance to drought and temperature extremes, improved grain quality, and resistance to a variety of diseases and insect pests have been identified. In 2003, quantitative trait loci (QTLs) were identified for many stress-physiology traits associated with drought tolerance. Researchers also identified molecular markers that can be used in marker-assisted selection for drought tolerance in Mediterranean dryland environments.

Improving drought tolerance using stress-physiology traits and molecular markers

Drought stress negatively affects the growth and development of plants, and is a major cause of reduced durum yields in dry areas. Researchers at ICARDA are, therefore, working to understand the genetic and physiological basis of drought tolerance, and develop efficient breeding techniques and drought-tolerant cultivars.

Although no single trait confers universal drought tolerance, many constitutive traits have a considerable impact on crop performance. For example, ICARDA has shown that high water-use efficiency (WUE) is strongly correlated with high carbon isotope discrimination (CID). Crop canopy temperature is

Screening genetic material for stress-physiology traits.

another indicator that reflects drought tolerance, as a higher canopy temperature is associated with lower crop transpiration. In addition, leaf chlorophyll content can also be used as an indicator of a crop's potential photosynthetic capacity. In ICARDA's durum breeding program, these traits, which are related to WUE, relative water content (RWC), and dryland grain yield (GY), have already been found to play a major role in drought tolerance.

Molecular markers are increasingly being used as a tool for genetic improvement because all the physiological, morphological, and developmental changes that confer drought tolerance in plants have a molecular genetic basis. Marker-assisted breeding overcomes the need for the large number of testing and breeding sites necessary for conventional breeding based on phenotypic expression.

ICARDA is, therefore, using molecular mapping techniques to locate regions of the genome that contribute to drought tolerance in durum, to better understand drought resistance, and to generate markers for use in marker-assisted breeding. To detect the factors that control the expression of important traits, genetic linkage maps are needed. ICARDA's durum breeding program has developed several mapping populations for different traits and environments. For drought tolerance and grain quality, two populations were developed: 'Jennah Khetifa' × 'Cham 1' and 'Omrabi 5'/*Triticum dicoccoides* 600545//'Omrabi 5.' For tolerance to drought and salinity, 'Omrabi 5' × 'Belikh 2' was developed. Researchers also created the 'Sw-algia' × 'Gidara 1' population for resistance to *Septoria tritici* leaf spot disease, and the 'Bezaiz 98-2' × 'Cham 1' and 'CI115' × 'Gidara 2' populations, for resistance to Hessian fly. For specific environments, scientists developed the following populations: (i) 'Haurani' × 'Cham 1' (for the continental areas of West Asia); (ii) 'Lahn' × 'Cham 1' (for CWANA's irrigated areas); (iii) 'Cama di Abbou' × 'Cham 1' (for temperate areas); (iv) 'Kunduru' × 'Cham 1' (for the highlands of the Anatolian plateaus); and (v) 'Oued Zenati' × 'Cham 1' (for the continental and the high plateau of the Atlas mountains).

Detection of QTLs for stress-physiology traits

Quantitative trait loci (QTLs) were found in the 'Jennah Khetifa' × 'Cham 1' population for all the stress-physiology traits studied. Drought-tolerance QTLs were located on chromosomes 1B, 2A, 3B, 4B, 5A, 5B, 6A, 6B, and 7B. QTLs were identified for canopy temperature depression, chlorophyll content and fluorescence indices (indicators of photosynthesis), as well as CID, RWC, and WUE.

Many of the QTLs for different traits overlapped. For example, canopy temperature depression, RWC, and WUE were all mapped to the same chromosomal region. The QTLs for transpiration and CID were mapped close to the locus gwm389. This indicates that either there are closely linked genes in one chromosomal region (linkage), or that the same gene affects different traits (pleiotropy). The distinction between linkage and pleiotropy is important; so, ICARDA plans to conduct fine resolution mapping to clarify this issue. Researchers also found that *Loxmjt* (a gene that codes for lipoxygenase) co-segregated with QTLs for canopy temperature depression, CID, and water-use efficiency on chromosome 4B. *Lox11-1* (which also codes for lipoxygenase) co-segregated with a QTL for photosynthesis under moisture-stressed conditions on chromosome 5B.

In the 'Jennah Khetifa' × 'Cham 1' mapping population, researchers found QTLs for CID, which is associated with WUE and thus drought tolerance. Three microsatellites were found to be linked to the CID-QTLs identified: two on chromosome 4B (Xgwm495, Xgwm368) and one on 7B (Lox1&3bp249). These explained 19.5% of the total variability of CID in the mapping population.

Validation of QTLs linked to drought tolerance using ICARDA's durum core collection

To validate the QTLs for CID found in the 'Jennah Khetifa' × 'Cham 1' population, the three microsatellite markers linked to them were probed on the 125 accessions in the ICARDA durum core collection. Accessions containing these markers were grown in the field at Tel Hadya, Syria, where researchers measured their CID, grain yield and other stress-physiology traits. Grain yield under dry conditions was found to be positively and strongly correlated with CID, RWC, and WUE (Table 3). These results clearly

Table 3. Correlations between grain yield and stress-physiology and grain-quality traits in durum.

	Stress-physiology traits			Grain-quality traits			
	CID	RWC	WUE	AC	PC	SDS	YP
Grain yield	0.553 ***	0.292 ***	0.920 ***	-0.697 ***	-0.751 ***	-0.419 ***	-0.073 ns

CID = grain carbon isotope discrimination; RWC = plant relative water content; WUE = grain water-use efficiency; AC = grain ash content; PC = grain protein content; SDS = grain sedimentation test; YP = grain yellow pigment.
ns: not significant; ***: Significant ($p < 0.001$).

Table 4. Association of QTLs linked to carbon isotope discrimination (CID) with grain yield and stress-physiology traits[1], in different accessions in the ICARDA durum core collection.

Marker/ Trait	Marker present	Marker absent	Signif. level[2]	Marker/ Trait	Marker present	Marker absent	Signif. level[2]
gwm495				Lox1&3			
No. of accessions	31	79		No. of accessions	74	42	
CID (%)	13.9	13.8	***	CID (%)	13.7	14.1	***
WUE (kg/mm)	7.7	7.3	*	WUE (kg/mm)	7.2	8.1	***
RWC (%)	72.6	72.7	*	RWC (%)	70.6	75.5	***
Grain yield (kg/ha)	3132	2978	*	Grain yield (kg/ha)	2917	3297	***
gwm368				gwm493			
No. of accessions	31	79		No. of accessions	63	58	
CID (%)	13.9	13.7	**	CID (%)	13.9	13.7	***
WUE (kg/mm)	7.7	7.3	*	WUE (kg/mm)	8.2	6.8	***
RWC (%)	72.5	72.7	*	RWC (%)	72.7	71.7	ns
Grain yield (kg/ha)	3131	2977	*	Grain yield (kg/ha)	3318	2788	***

[1] WUE = water-use efficiency; RWC = relative water content.
[2] Significance levels for differences between means for accessions in which markers were and were not present: ns: not significant; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

indicate that CID is useful as an indirect selection criterion for grain yield in dryland areas.

ICARDA researchers also assessed the effect of the presence and absence of some molecular markers identified as QTLs for CID in the 'Jennah Khetifa' × 'Cham 1' population, when probed on the durum core collection. Many significant differences between those accessions that did or did not have markers were found for mean CID, WUE, RWC, and grain yield. Thus, the QTLs detected in the mapping populations were also validated in the durum core collection (Table 4). In particular, the markers gwm495, Lox1&3 and gwm368 (the candidate CID-QTLs in the 'Jennah Khetifa' × 'Cham 1' population) were strongly related to WUE, RWC, and grain yield.

These results indicate the relevance in marker-assisted selection of the detection of QTLs in the mapping population. In this QTL-validation study, grain yield and drought tolerance showed significant relationships with QTLs and molecular markers. The results support the use of a marker-assisted selection program to improve durum productivity and drought tolerance in Mediterranean dryland environments.

Project 1.3. Spring Bread Wheat Germplasm Improvement for Increased Productivity, Yield Stability, and Grain Quality in West Asia and North Africa

Bread wheat is the principal food source for most people in CWANA. The average person in the region consumes more than 170 kg per year, the highest per capita consumption of wheat in the world. However, bread wheat production in CWANA is limited by disease, particularly yellow rust. New races of the yellow rust fungus, break down the defenses of previously resistant wheat varieties. Therefore, in 2003, ICARDA researchers continued to identify partially resistant wheat varieties, which have long-lasting, 'slow-rusting' resistance based on a number of minor genes. Testing showed that yield losses in these varieties were negligible, despite high infection rates—a result of the considerably slowed down disease development. More emphasis is now being placed on enhancing durability of rust resistance to reduce the risks of yellow rust epidemics and enhance production stability.

'Slow-rusting' resistance: enhancing the durability of yellow rust resistance in bread wheat in CWANA

Despite the high demand for bread wheat in CWANA, the total wheat production is not enough. This is partly due to low yields and the many diseases that limit wheat production in the region.

A major disease of bread wheat is yellow rust, or stripe rust, caused by the fungus *Puccinia striiformis* f. sp. *tritici*. Over the past decade, several yellow rust epidemics have occurred in Afghanistan, Egypt, Ethiopia, India, Iran, Lebanon, Pakistan, Syria, Turkey, and Yemen, causing up to 40% yield losses. Because of its ability to mutate and form new races, and because its wind-dispersed spores can travel long distances and affect large areas, yellow rust continues to threaten the stability of wheat production in CWANA.

Genetic resistance is widely used to control rust diseases. It is recognized as the most environmentally friendly and economic control measure, since farmers who grow a resistant variety do not have to buy fungicide. However, until recently, most of the resistance was based on a single major gene or on combinations of certain genes. As wheat breeders have known for some time, deployment of such disease-race-specific, hyper-sensitive genes usually results in the evolution of rust races with virulence for such genes or gene combinations. In turn, this causes 'boom and bust' cycles, as the resistance is usually only effective for about five years.

An alternative is the use of genes that confer race-nonspecific, 'slow-rusting' resistance. Plants with these genes have partial resistance, which slows the rate of disease development. So, despite the fact that infection rates can be high, the disease only has a slight effect on grain yield. This kind of resistance has proved to be more durable than race-specific resistance. With the aim of developing durable resistance, ICARDA's spring bread wheat improvement program strategically shifted its resistance-breeding methodology to this approach in 1998.

To find new lines with 'slow-rusting' resistance, ICARDA now conducts intensive screening

Table 5. Disease development and yield loss due to yellow rust in eight spring bread wheat cultivars evaluated for two seasons in Aleppo, Syria, under protected (rust-free) conditions and artificial infection with yellow rust.

Cultivars	Disease development						Mean grain yield		Yield loss	Resistance
	Response[1]	FDS (%)[2]		AUDPC[3]	RAUDPC[4]	Rate[5]	Protected	Non-protected		Type[6]
		Range	Mean				(kg/ha)	(kg/ha)	(%)	
'Cham-2' (Susceptible-Check)	S	95-99	98	1717	100	27.42	5219	1126	78	1
'Mexipak' (Susceptible-Check)	S	95-99	96	1489	87	25.08	4425	1815	59	1
'Cham-8' (Partially Resistant-Check)	MS	10-45	22	411	24	6.81	5827	5390	8	2
'Booma-2'	MS	10-30	21	376	22	6.14	4909	4453	9	2
'Bashiq-1'	MR-R	1-10	4	71	4	1.34	5774	4866	16	3
'Cham-6' (Resistant-Check)	MR-R	5-10	6	70	4	1.41	6201	5550	10	3
'Hudhud-10'	R-MR	1-10	5	56	3	1.23	5060	3975	21	3
'Asfoor-4'	R-MR	0-10	4	55	3	1.10	5343	4638	13	3

1 S = Susceptible; MS = Moderately susceptible; MR-R = Moderately resistant to resistant; R-MR = Resistant to moderately resistant.
2 FDS = Final disease severity (percentage of leaf infected).
3 AUDPC = Area under disease-progress curve.
4 RAUDPC = Relative area under disease-progress curve (AUDPC, expressed as a percentage relative to the value of the most susceptible cultivar).
5 Rate = Rate of yellow rust progress per day after inoculation.
6 Resistance type: 1 = Susceptible; 2 = Partial/slow rusting; 3 = Complete/hyper-sensitive.

Intensive screening of new spring bread wheat germplasm for long-lasting partial/'slow-rusting' resistance to yellow rust disease.

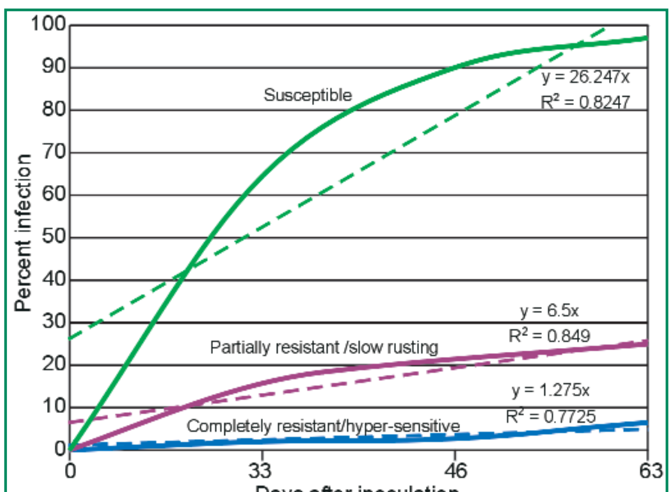


Fig. 9. Yellow rust progress curve for susceptible, partially resistant/'slow-rusting,' and completely resistant groups of spring bread wheat cultivars evaluated in Aleppo, Syria, during two growing seasons (2000-2002).

programs, using heavy artificial infection to simulate yellow rust epidemics. Data on disease development are collected over time during the cropping season, allowing researchers to calculate the area under the disease progress curve (AUDPC)—an effective measure of disease development on cereals. Figure 9 shows the yellow rust disease progress curve for susceptible, 'slow-rusting', and resistant cultivar groups, over the 2000-2002 growing seasons. The disease-development rates per day were 26%, 7%, and 1% respectively, indicating that partial resistance/ 'slow-rusting' greatly reduced the rate of disease development. It also reduced grain yield losses to levels similar to those of hyper-sensitive, race-specific, resistant cultivars (Table 5). Thus, this germplasm offers long-lasting, durable resistance without affecting yields.

Screening will continue to identify more 'slow-rusting' genotypes for use by national agricultural research programs. The early products of this strategy, such as 'Booma-2,' are already being distributed through international nurseries.

Project 1.4. Winter and Facultative Bread Wheat Germplasm Improvement for Increased Yield and Yield Stability in Highlands and Cold Winter Areas of Central and West Asia and North Africa

The production of facultative and winter bread wheat, grown predominantly in developing countries, is not enough to meet demand. ICARDA is working in partnership with CIMMYT and Turkey's national agricultural research system to improve yields. As a result, CWANA's NARS released nine new varieties of facultative winter wheat in the 2002/03 season. Researchers also identified early-maturing wheat germplasm which will allow farmers to plant a second crop (maize or cotton) after winter wheat. The release of new, resistant varieties has minimized the risk of yellow rust epidemics which can cause considerable crop losses in Central Asia. ICARDA also addressed the important issues of technology and knowledge transfer in 2003. On-farm demonstrations and fast seed multiplication ensured that farmers received seed of new varieties as quickly as possible, while traveling workshops at 16 sites in Uzbekistan allowed farmers to assess promising new winter wheat varieties.

High-yielding, resistant wheat varieties for CWANA and CAC

The developing world's major winter and facultative wheat growing areas are in Afghanistan, Central Asia, Iran, Turkey, and the Atlas mountains in North Africa. The total winter and facultative wheat area of CWANA is around 16.4 million hectares, 67% of which is rainfed.

In CWANA, more than 90% of the wheat grown is used for food. Wheat often provides more than half of the calories in people's daily diets. But CWANA's populations are growing more rapidly than the average for developing countries, and most countries are striving to produce as much wheat as possible to meet domestic demand. For example, as much as 70% of arable land is planted with wheat in Turkey and Iran, the two largest winter wheat producers in the region.

The ICARDA/CIMMYT/ Turkey International Winter Wheat Improvement Project (IWWIP) is continuing to develop and identify improved varieties for use in CWANA. Wheat breeders from CWANA and researchers from ICARDA and CIMMYT are collaborating to develop and identify promising lines suited to the specific conditions found in the CWANA region. In the 2002/03 cropping season, nine varieties were released by the NARS of Afghanistan, Georgia, Turkey, and Uzbekistan; 17 more varieties are undergoing first-year registration trials (Table 6). Wheat breeders in CWANA have identified promising

Table 6. Wheat cultivars derived from the International Winter Wheat Improvement Program, released or submitted for registration in CWANA, in the 2002/03 season.

Country	Status	Varieties
Turkey	Released	'Soyer,' 'Yildirim,' 'Daphan,' 'Bagci,' 'Nenehatun,' 'Sakin'
	Submitted	Shark/F4105 W2.1, S/Tap-01/24
Afghanistan	Released	'Solh'
Uzbekistan	Released	'Dostlik'
Georgia	Released	'Mtshetskaya 1'
Armenia	Submitted	ATGF-1, ATGF-2, ATGF-3, ATGF-4, ATGF-5, Dagdas-94
Kyrgyzstan	Submitted	'Keremet,' 'Zagadka,' 'Zubkov,' 'Azibrosh,' 'Aychurek,' 'Cholpon'
Tajikistan	Submitted	'Alex,' 'Ormon'
Kazakhstan	Submitted	'Akdan'


ICARDA Director General and Board of Trustees visiting on-farm demonstration fields *(left)* and winter and facultative wheat research activities at the farm of Tashkent State Agriculture University, Uzbekistan *(right).*

lines among those distributed by IWWIP through the international nursery system. Many of these have been widely used in breeding programs as sources of valuable traits and qualities.

The major national objective of several Central Asia and the Caucasus (CAC) countries is self-sufficiency in food production. Most commercial wheat varieties in the CAC region were either developed locally or originated from the former Soviet Union, and are highly susceptible to yellow rust. In the last decade, Central Asian farmers suffered wheat losses as high as 50% in two major yellow rust epidemics. Through the selection of resistant varieties from IWWIP, breeding programs in Central Asia have substantially reduced the risk of such epidemics. During the last four years of collaborative research, six promising winter wheat varieties have been released by NARS in the CAC region. These varieties have consistently yielded 10-25% more than local check varieties, and have better tolerance to cold and resistance to disease (Table 7). In addition, more than 15 varieties are currently being tested in State Varietal Trials before their release and large-scale distribution.

Table 7. Grain yield (t/ha) of promising wheat varieties compared with local checks in on-farm trials in CAC countries, and the amount of seed produced for release to farmers.

Country	Variety/line	Productivity (t/ha)	Average yield gain over check(%)	Available seed (t)
Armenia	'Ani-326'	6.5	16	
Georgia	'Mtshetskaya 1'	5.6	16	25.0
	'DAGDAS-94'	5.2	18	0.6
Kazakhstan	'Egemen'	6.8	20	60.0
	'Akdan'	6.2	20	56.0
Kyrgyzstan	'Jamin'	8.6	25	25.0
	F474	6.3	22	4.0
Azerbaijan	'Azamely-5'	7.8	25	200.0
	'Gobustan'	7.2	22	30.0
	'Nurlu-99'	6.8	18	200.0
Tajikistan	'Tacicar'	7.2	15	0.3
	'Norman'	6.8	12	0.3
	'Kauz'	6.3	18	0.3
	'Alex'	6.2	15	nd
	'Ormon'	6.8	12	nd
Turkmenistan	'Bitarap'	6.3	22	0.3
	'Guncha'	6.2	15	9.0
	'Garagum'	5.8	12	14.0
Uzbekistan	'Dostlik'	7.3	22	1000.0
	'Ravat'	7.2	20	0.5
	'Grecum'	6.8	18	0.5

nd = no data.

Transferring new technologies to farmers in CAC countries

In 2003, ICARDA continued to contribute to wheat research in CAC through the promotion and support of technology transfer by conducting on-farm demonstrations and ensuring fast seed multiplication of promising new lines. During the 2002/03 growing season, on-farm trials and demonstration plots were established in 16 locations, representing all the wheat-producing zones of Uzbekistan. Variety testing, on-farm trials, and field demonstrations will continue with support from ICARDA and various NARS.

A traveling workshop for researchers and farmers from Uzbekistan was also organized by ICARDA, in collaboration with Uzbekistan's Ministry of Agriculture. Fifty-one participants visited the 16 on-farm demonstration sites set up by the project to assess the performance of new winter wheat varieties. Participants jointly identified four entries as promising ('Bukhora-Sharif,' 'Mira,' 'Durdona,' and 'Fravo'); these will now undergo a final round of testing by the country's State Variety Testing Commission before release.

Project 1.5. Food Legume (Lentil, Kabuli Chickpea, and Faba Bean) Germplasm Improvement for Increased Systems Productivity

Lentil, chickpea, and faba bean, are important cool-season food legumes in CWANA. In addition to being a major source of dietary protein (particularly for the poor), they play an important role in maintaining and improving soil fertility, and make farming systems more sustainable. In 2003, a large number of high-yielding, *Ascochyta* blight resistant, and cold-tolerant chickpea lines were developed for winter sowing. In the CAC region, efforts focused on adaptation of elite chickpea cultivars and the development of elite lines with combined resistance to *Ascochyta* blight and *Fusarium* wilt. Two elite cultivars were released, and 12 more were submitted for registration in CAC countries. Two cultivars were released in Ethiopia, and one in Tunisia. In faba bean, nutritional quality was improved as new lines with low levels of anti-nutritional factor were developed that were auto-fertile and resistant to *Ascochyta* blight and chocolate spot. Progress was made in developing improved faba bean lines, resistant to these diseases and also to the parasitic weed *Orobanche*. Progress has been made working with farming communities in Bangladesh and Nepal, where the improved lentil cultivars are in great demand. Researchers concentrated on developing lentil lines with *Fusarium*-wilt resistance, winter-hardiness for high altitudes, and early, large-seeded types for southerly latitudes.

Potential and prospects of chickpea in CAC countries

Diversification of cropping systems is essential for sustainable agriculture in Central Asia and the Caucasus. Introduction of chickpeas in the cereal-based cropping systems is being attempted to avoid monocropping.

Cooperative research is, therefore, being conducted on chickpea improvement with the NARS in the CAC region. A large number of elite chickpea lines developed by ICARDA have been shared with the national programs of different CAC countries.

In Azerbaijan, a chickpea variety 'Narmin' (FLIP 95-65C) was released. Planted in the winter in Jalalabad, Azerbaijan, it outyielded the local cultivar 'Behovaskaya,' which is susceptible to *Ascochyta* blight, by 18-20% over the last three years. It is taller, hence suitable for mechanical harvesting and has bigger seeds. It has also demonstrated a high yield potential (2500 kg/ha) in farmers' fields.

In Armenia, three promising chickpea lines were identified: FLIP 97-121C, FLIP 98-130C, and FLIP 99-48C. These were included in the 2003/04 season on-farm evaluations and field demonstrations.

Georgia's Mtskheta Breeding Station released the chickpea variety 'Elixir' (ILC 533), which is high-yielding (3500-4000 kg/ha), has a better standing ability and larger seeds than local varieties. The variety is being widely adopted in the Marneuli, Gurdjaani, and Signaghi regions of Georgia. The Mtskheta station also identified a number of other promising lines, including ILC 3279 and ILC 6249.

The Georgia Agrarian State University is also actively involved in the transfer of technologies to farmers. A large quantity of 'Elixir' seed was distributed to farmers for planting in the Narikwal region.

Scientists from the Kazakh Research Institute of Crop Husbandry have identified a number of improved chickpea lines. The line, FLIP 97-137C, was released as 'ICARDA-1.' The State Variety Testing Commission found that 'ICARDA-1' gave higher yields, and was more resistant to *Ascochyta* blight than the local check 'Kamila.' A large quantity of 'ICARDA-1' seed was, therefore, produced in Almalybak, and distributed to farmers for planting in the 2003/04 season. Another line (FLIP 94-25C), which has a high seed yield and tolerance to *Ascochyta* blight, was identified in Krasny-Vodopad

Recently released 'Narmin' (FLIP 95-65C) chickpea in Azerbaijan.

'Elixir,' a new chickpea variety identified from ICARDA-supplied elite materials, is released in Georgia.

(South Kazakhstan) and will be submitted to the registration committee for release.

In Turkmenistan, three high-yielding improved lines (FLIP 98-131C, FLIP 98-48C, and FLIP 82-150C) were identified for testing in on-farm trials. As well as a good level of productivity, these lines have demonstrated better disease resistance, and better heat and drought tolerance, than local varieties. They were submitted to the country's State Variety Testing Commission for testing and release.

Two lines, FLIP 97-149C and ILC 3279, which gave a consistently good performance across different years, were selected for evaluation in three agroecological environments in Tajikistan, and are candidates for registration and release. The Tajik Research Institute of Crop Husbandry further identified FLIP 99-66C, FLIP 99-30C, FLIP 99-61C, FLIP 99-47C, and FLIP 98-15C as promising. These lines outyielded the local check ('Muktadir') and were found to be *Ascochyta* blight resistant. They will be evaluated in multilocation trials during the 2003/04 season.

Uzbekistan is the main chickpea producer in the CAC region. The Galla-Aral and Andijan Research Institutes undertake the country's chickpea research, while the Uzbek Research Institute of Plant Industry performs necessary quarantine activities and supplies any imported material to the relevant institutes for in-depth evaluation. After several years of testing and evaluation, legume breeders from Galla-Aral have selected five promising lines from ICARDA nurseries (FLIP 88-85C, FLIP 93-93C, FLIP 97-99C, FLIP 87-8C, and FLIP 95-55C), all of which performed better than the standard check. In 2003, two of these lines (FLIP 88-85C and FLIP 93-93C) were put forward as candidates for registration and release. In Andijan, a number of elite chickpea lines (FLIP 98-23C, FLIP 95-74C, FLIP 97-25C, FLIP 98-44C, and FLIP 97-95) were also identified from ICARDA-supplied nurseries. As well as producing bigger seeds than 'Uzbek-32' (the standard check), all are erect, have a good podding intensity, and reach maturity early. In trials, FLIP 98-23C has demonstrated its superiority in on-farm conditions and will be submitted for registration and release.

Kazakhstan chickpea scientist Dr Baizomat Janizbayev discusses the performace of winter chickpea in a chickpea research plot at Almalybak, Kazakstan with ICARDA's Dr Victor Shevtsov *(right).*

Clearly, progress has been made in selecting promising chickpea lines in the CAC countries. With technical and, to some extent, financial support from ICARDA, the national programs are already taking steps to release these new lines and to ensure the production and dissemination of good quality seed. On-farm demonstrations and field days are being organized, and farmers are being trained in the use of chickpea production packages. Strong links are also being established between farmers and extension and research personnel. In addition, efforts are being made to increase the quantities of seed available from each of the released varieties/pre-release lines, to allow faster dissemination to farmers.

Closely linked di- and trinucleotide microsatellites do not evolve in complete independence in chickpea

In recent years, microsatellite markers have become the markers of choice for the characterization of germplasm accessions and analysis of population structures. They are used both to study sub-populations within species and to elucidate the evolutionary relationship between species. This ultimately helps researchers develop new varieties through breeding programs. Several genetic distance measures have been specifically developed for use with microsatellite data, all of which assume that microsatellite loci evolve independently and follow some form of the stepwise mutation model. Previously, ICARDA showed that the mutation patterns at these loci differ considerably (both with respect to mutation rate and mutation bias), and recommended the use of microsatellite loci with similar mutation rate and mutation bias properties. During a study on allelic variation at closely linked $(TA)_n$ and $(TAA)_n$ microsatellite loci in 114 landraces of chickpea sampled worldwide, ICARDA researchers found that closely linked di- and trinucleotide microsatellites do not evolve in complete independence in chickpea.

The two loci studied are located close to each other, and are separated by only 27 base pairs (bp). ICARDA researchers discovered that each locus exhibits a very high degree of polymorphism. Hence, the combined length of the two loci was found to vary greatly between the samples. This was reflected in genetic diversity measures of 0.93, 0.90, and 0.98 for $(TAA)_n$, $(TA)_n$ and the combined length, respectively.

To study the biology of recombination of the linked loci, data on the amount of variation occurring at the two linked loci was used to compute a standardized index of linkage disequilibrium. The value of this index was significant (I^S_A = 0.092), indicating that the two loci were non-randomly associated with each other, and would not be inherited independently.

Furthermore, the dynamics of allelic variation revealed a threshold combined length, below which both $(TAA)_n$ and $(TA)_n$ loci evolve independently, and above which, if one locus increases in size, the other closely linked locus has a tendency to decrease its size and vice versa, without any change occurring in the overall ratio of $(TAA)_n$ and $(TA)_n$ allele sizes in the region. This result indicates that there are processes in the cell that involve the 'reading' of the combined size of the two loci, for both proportion and length, and which determine the direction of tightly linked di- and trinucleotide repeat evolution.

The study showed clearly that tightly linked microsatellite loci do not evolve in complete independence. As a result, researchers should be cautious when choosing microsatellite loci for genetic characterization and population genetic studies including association genetics. In addition to using microsatellite loci with similar properties (with respect to mutation rate and mutation bias) for characterization of germplasm accessions and analysis of population structures, researchers should choose well-isolated microsatellite loci with no other microsatellites in close proximity.

Developing auto-fertile faba bean lines with combined resistance to chocolate spot and *Ascochyta* blight

Slight genetic variations can cause differences in the flower structure of different faba bean lines. This is important because the relative positions of the flower's stigma and pollen-bearing anthers determine where pollen falls, and thus whether a plant can be fertilized with its own pollen (auto-fertility). A number of breeding programs have concentrated on developing auto-fertile cultivars, several of which have already been released in the UK. Auto-fertile cultivars would have the advantage of being able to yield well even in the absence of suitable insect pollinators, resulting in improved yields. However, most auto-fertile lines are highly susceptible to leaf diseases. ICARDA is, therefore, working to develop new faba bean lines that combine the advantages of auto-fertility with resistance to leaf diseases.

A promising auto-fertile line ***(left)*** **of faba bean performed better than the best check ('Giza 40' or 'Rebaya 40') in screen houses at Lattakia, Syria 2003.**

The fungal diseases that cause the most damage to faba bean in different parts of the world are chocolate spot, caused by *Botrytis fabae*, and *Ascochyta* blight, caused by *Ascochyta fabae*. Chocolate spot can reduce yields by 50% if infection occurs early in the season, and *Ascochyta* blight can cause yield losses of 5-50% depending on severity, and reduce seed quality.

Over the last seven years, researchers at ICARDA have focused on combining auto-fertility with resistance to chocolate spot and *Ascochyta* blight. This has led to the development of two improved populations (1-HBP/ BS_0/ 99 and 2-HBP/ BS_0/ 99). Population 1-HBP/ BS_0/ 99 was derived from 14 crosses between 15 germplasm accessions resistant to chocolate spot disease (L 83109, BPL 710, BPL 266, BPL 2282, ILB 3025, L 82010, BPL 1179, B8838, R. 8828, B 8839, L 83106, L 83108, L 83117, L 83129, and Sel. 82 Lat) and 6 improved lines and/or varieties from NARS ('Giza Blanca' and 'Rebaya 40' from Egypt; 'S.T.W.' from Sudan; 'CS 20 DK' from Ethiopia; VF from Iraq; and 'ERESEN-87' from Turkey). Population 2-HBP/ BS_0/ 99 was derived from three-way crosses, including BPL 465 × S96007, L 82003-1 × S96 008, and BPL 1179 × S 960013.

The F_1 plants were raised in screen houses at Tel Hadya during the 1996/97 and 1997/98 growing seasons. The F_2 populations were then compared with other varieties at two locations during the 1998/99 season. In Lattakia, Syria, they were compared with the auto-fertile accession 'Rebaya 40,' which is highly susceptible to chocolate spot disease and the highly resistant check 'ICARUS.' At Tel Hadya, the F_2 populations were compared with 'Giza 4,' which is highly susceptible to *Ascochyta* blight, and the highly *Ascochyta* blight resistant check 'Ascot.'

In Lattakia, the plants were subjected to both natural and artificial infection with chocolate spot in the screen houses (in the absence of insect pollinators), while

Table 8. Average numbers of pods and seeds per plant, yield per plant and 100-seed weight of 40 F_6 lines, compared with an auto-fertile (A) check and checks resistant (R) or susceptible (S) to chocolate spot or *Ascochyta* blight disease during the 2002/03 season in Syria.

Population	Resistance to disease[1] Chocolate spot	*Ascochyta* blight	Pods/ plant	Seeds/ plant	Yield/ plant (g)	100-seed weight (g)	Location
F_6 Lines[2]	3.0	4.5	6.8	18.4	13.2	71.7	Lattakia[3] & Tel Hadya
'Rebaya 40' (A,S)	6.0		8.6	17.9	13.1	73.2	Lattakia[3]
'ICARUS'(R)	2.2		6.4	13.4	5.8	43.3	Lattakia[3]
'Ascot' (R)		5.8					Tel Hadya
'Giza 4' (S)		7.4					Tel Hadya

[1] 1 = highly resistant, 9 = highly susceptible.
[2] Mean values of 40 lines.
[3] Results from screen houses, in the absence of insect pollinators.

at Tel Hadya, plants were artificially infected with *Ascochyta* blight under open-field conditions. Using a scale of 1 to 9, the segregating populations (F_2-F_6) were evaluated, over five growing seasons (from 1998/99 to 2002/03), for resistance to the two diseases. In both locations lines were selected that combined disease resistance with auto-fertility (indicated by high numbers of pods and seeds per plant). Results showed that 40 of the F_6 lines combined auto-fertility with high levels of resistance to chocolate spot and *Ascochyta* blight (Table 8).

Fusarium wilt—no longer a threat to lentil

Lentil was one of the first food crops to be domesticated in the Fertile Crescent (around the Tigris and Euphrates rivers). Over time, it spread from West Asia to South Asia, Central Asia and the Caucasus, northwestern China, North and East Africa, the Americas and Oceania. The crop now plays an important role in cereal-based cropping systems, particularly in less favorable areas with low rainfall and low soil fertility. However, lentil suffers from a range of biotic and abiotic stresses. Of the biotic stresses, vascular wilt (a fungal, soilborne disease) is the most damaging. Lentil wilt is caused by several species of *Fusarium*, but the most devastating is *Fusarium oxysporum* f. sp. *lentis*. Yield losses of up to 72% have been recorded in Syria, and complete crop failure has been reported in other areas where conditions favor infestation, especially in years with warm temperatures in the spring.

Since its inception, the lentil-breeding program at ICARDA has been developing and delivering wilt-resistant germplasm to national programs. Host-plant resistance is the most economically feasible and environmentally friendly way of controlling Fusarium wilt in lentil, as farmers do not need to buy fungicide. A key role in the development of such resistance is played by the well-established (14-year-old) 'wilt sick plot' (WSP) at ICARDA's Tel Hadya research station, in which plant material is screened for resistance to wilt. Material found to be resistant is then used to develop new breeding lines.

To do this, resistant parents with good agronomic performance are crossed, and the segregating populations are advanced to the F_4 generation. From these F_4 generations, single plants are selected and plant-progeny rows (families) are developed. In this process, thousands of F_5 families are screened in the WSP for wilt resistance and other desirable agronomic traits. In subsequent breeding cycles, the selected lines are tested in the WSP in 50-cm single-row plots in preliminary screening nurseries (F_6), preliminary yield trials (F_7), and advanced yield trials (F_8). Lines confirmed as resistant after four generations are included in international nurseries, for dispatch to national programs. Highly resistant, advanced lines are being made available to national programs through a specific Lentil

Screening for *Fusarium* wilt resistance in lentil at Tel Hadya, Syria, 2003.

International *Fusarium* Wilt Nursery (LIFWN).

Many national programs have identified promising lines from ICARDA-supplied materials, and have released varieties with high levels of resistance to *Fusarium* wilt. For example, Syria has recently released three wilt-resistant improved varieties: 'Idlib-2,' 'Idlib-3,' and 'Idlib-4.' The key characteristics of these varieties are shown in Table 9.

'Idlib-3,' a high-yielding and disease-resistant lentil variety released in Syria in 2002.

The seed of these three varieties is currently being multiplied and distributed to Syrian farmers; 24 t of 'Idlib-2' and 7.5 t of 'Idlib-3' seed, for example, has been distributed to the farmers in five lentil-growing provinces in the country. At the same time, farmer-to-farmer seed diffusion is occurring spontaneously. Three wilt-resistant varieties have also been released in neighboring Lebanon: 'Talya-2,' 'Rachayya,' and 'Hala.' In Iraq, farmers are cultivating an ICARDA-derived wilt-resistant variety: 'IPA-98.' In southeast Anatolia in Turkey, wilt-resistant cultivars released by the Southeast Anatolian Regional Agricultural Research Institute (SARARI), at Diyarbakir, are being widely cultivated in lentil-growing areas. In Ethiopia, farmers are cultivating the varieties 'Adaa,' 'Alemaya,' and 'Assano,' which are resistant to both wilt and root rot; therefore, the area planted to lentil has increased rapidly in recent years. Nepalese scientists have identified six promising lines with high levels of resistance to the wilt–root-rot complex, some of which have reached the seed-multiplication and pre-release stages. Many national programs have also conserved their own sources of wilt resistance and used these in their breeding programs.

ICARDA's breeders and pathologists are continuously searching for new and diverse sources of resistance to combat the evolution of new disease races, and are pyramiding those resistance genes. The Center has screened its collection of lentils from around the world (more than 10,000 cultivated and 500 wild lentil accessions), identifying many sources of wilt resistance. During the last four years of screening, researchers have selected 34 accessions with stable resistance, originating from 14 countries. Many of the lines are now being used in hybridization programs.

Table 9. Characteristics of wilt-resistant lentil varieties in Syria.

Varieties	Year of release	Days to maturity	Seed yield (t/ha)	Biomass (t/ha)	100 seed wt. (g)	Wilt incidence (%)
'Idlib-2'	2000	154	1.25	3.97	3.73	<5
'Idlib-3'	2002	150	1.30	3.72	3.02	<5
'Idlib-4'	2002	154	1.35	4.0	3.04	<5
ILL 2130 (Local check)	-	155	1.1	4.1	2.07	Up to 70

Research for the poor—a successful partnership with NARS in Bangladesh

Lentil is the most important pulse crop in Bangladesh. Usually served as *dhal* (a thick soup) with rice, lentil is considered to be 'poor man's meat' in Bangladesh, because of its high protein content. Indeed, most of the country's 140 million people rely on pulses for protein. Lentil is also rich in micronutrients, including iron, zinc, and β-carotene, which are essential for human health, particularly in the case of pregnant women and growing children. Its straw is a valuable animal feed. Moreover, when planted in rotation with rice, lentil adds nitrogen to the soil and helps break pest and disease cycles. But, Bangladesh's lentil production is too low to meet demand. This is because some farmers are still cultivating low-yielding landraces that are susceptible to disease, and also because the area planted to lentil is decreasing due to competition from other winter crops and the expansion of irrigated rice cultivation during the winter months. As a result, Bangladesh imports over 40,000 tonnes of lentil, at a cost of around US$18 million annually.

To address this problem, the national Pulse Research Center of the Bangladesh Agricultural Research Institute (BARI) has been collaborating with ICARDA since the early 1980s. BARI's participation in the ICARDA-led Legume International Testing Program (LITP) has led to the supply and joint testing of improved genetic materials with resistance to various stresses. ICARDA has also trained many of BARI's young scientists. This has led to improved research capability there, as well as to productive working relationships between the two institutions, thereby laying the foundation for the success in the country's lentil improvement work.

Overcoming an ancient 'bottleneck': Bangladeshi lentil's narrow genetic base

Until recently, the main problem limiting lentil improvement efforts in Bangladesh was the narrow genetic base of the country's lentil crop: little variability existed in the key traits that contribute to yield and disease resistance. ICARDA provided Bangladesh with exotic lentil germplasm, breeding lines, and segregating populations. This germplasm is a source of many valuable traits, including resistance to both biotic and abiotic stresses.

However, due to asynchrony in the flowering of the local cultivars and those of exotic origin, it was not possible to cross the two to incorporate exotic genes. It was decided that hybridization would be the best way forward. ICARDA was, therefore, requested to produce crosses specifically for Bangladesh, making use of the country's improved landraces and ICARDA germplasm with resistance to *Stemphylium* blight and rust—the most damaging lentil diseases in Bangladesh. In consultation with national breeders, crosses were planned and made at ICARDA under an extended photoperiod (18 hours plus) to improve synchrony in flowering and facilitate crossing with the Bangladeshi landraces. Wide crosses were made and many desirable genes were introgressed—including those for disease resistance. The genetic base of lentil was substantially broadened.

The targeted segregating populations developed at ICARDA were then sent to national programs in Bangladesh, where selections were made under local conditions—a decentralized breeding approach. Thus, the ancient 'bottleneck' was overcome, and a major breakthrough made in the field of plant genetics.

Subsequent research on varietal improvement undertaken by BARI and ICARDA resulted in the release of four improved lentil varieties, two of which emanated from ICARDA-supplied material. These short-duration varieties gave more stable and higher yields than traditional varieties, were resistant or tolerant to stemphylium blight and rust, and were suitable for inter-cropping or mixed-cropping systems (Table 10).

Table 10. Lentil varieties released by the Bangladesh Agricultural Research Institute (BARI) as a result of a partnership with ICARDA's lentil breeding program.

Variety	Year of release	Origin	Time to maturity (days)	Seed size: 100-seed weight (g)	Yield (t/ha)	Disease resistance
'Uthfala'	1991	Local landrace	110	1.6	1.3	Tolerant to rust
'Barimasur-2'	1993	ICARDA cross	110	1.5	1.8	Resistant to rust
'Barimasur-3'	1995	Local cross	115	2.5	2.0	Resistant to rust
'Barimasur-4'	1995	ICARDA cross	116	1.7	2.3	Resistant to rust and *Stemphylium* blight

Bangladeshi farmers discuss the performance of an improved lentil variety with ICARDA lentil breeder *(second from right).*

Farmer adoption and research impacts

The BARI–ICARDA partnership provided researchers, extension agents, and progressive farmers with formal training on the new lentil technology package. Details of the package were also circulated in the form of easy-to-understand leaflets, booklets, and posters in the local language. Demonstrations in farmers' fields and farmer field days were organized. To date, about 39,000 tonnes of seed of the improved varieties has been distributed to farmers, substantially increasing adoption rates. Spontaneous farmer-to-farmer seed dissemination, encouraged by technology-transfer mechanisms, has further ensured the spread of the improved lentil varieties.

To date, about 60,000 ha have been planted to improved varieties, mostly 'Barimasur-4.' Lentil farmers have also adopted related, improved, production practices,

Several transfer of technology mechanisms are being used to spread the adoption of new lentil varieties in Bangladesh.

including relay and mixed cropping, and intercropping. These have helped to further increase productivity and farmers' incomes. Bangladeshi farmers are now producing an additional 28,000 tonnes of lentil annually. With a farm gate price of US$450/tonne (Taka 25,650/tonne) these increases represent approximately US$12.6 million—saving the nation's valuable foreign exchange. An impact analysis found that the extra income earned from adopting improved lentil technologies was used by farmers to buy clothes (15.6%) and personal items (19.5%); to purchase rice and other foods (9.9%); to cultivate subsequent (summer) crops (16.6%); to educate their children (14.8%); to pay for medical treatment (13.7%); and to pay off loans (5.8%)—as well as for other purposes (4.1%), such as the purchase of cattle or threshers, the building of brick houses, and the repair of farm implements. Therefore, the on-going collaboration between BARI and ICARDA is a successful example of national–international research cooperation. It has contributed greatly both to the country's economy and to poverty alleviation, as well as to the nutritional security of the rural poor who cannot afford animal protein.

Project 1.6 Forage Legume Germplasm Improvement for Increased Feed Production and Systems Productivity in Dry Areas

Forage legumes—valued for their ability to provide high-protein animal feed, while simultaneously maintaining or improving soil fertility—are receiving increasing attention from scientists and farmers. ICARDA has developed improved lines of nutritious vetch (*Vicia* spp.) and chickling (*Lathyrus* spp.) suitable for low-rainfall areas and for cold, highland areas. Collaboration with NARS in seven countries resulted in the selection and release of new, well-adapted, high-yielding varieties in 2003. Scientists also developed a new line of common vetch containing non-toxic levels of an anti-nutritional factor that had previously precluded the use of vetch as animal feed. Experiments with an unusual and potentially very useful underground species of vetch showed that it could be used to produce large quantities of nutritious feed, rehabilitate degraded rangelands, and increase barley yields in barley/vetch rotations.

Developing nutritious, high-yielding feed legumes

CWANA's livestock populations are growing rapidly and threatening the sustainability of the rangelands, the main source of feed. This is resulting in accelerated rangeland degradation and a severe feed deficit. What is more, demand for crops is also increasing. This is expected to lead to the cropping of marginal land currently used for grazing, thereby exacerbating the problem. One solution to the feed problem is the development of improved indigenous forage legumes, such as vetches (*Vicia* spp.) and chicklings (*Lathyrus* spp.), for grazing, hay making or harvesting at maturity for seed and straw. Indeed, when livestock prices are high, the use of feed legumes—which may be fed to small ruminants both as straw and grain—is becoming an increasingly attractive option for farmers in CWANA.

ICARDA researchers are focusing on annual vetch and chickling species suited to dry areas (annual rainfall 250-350 mm). Located between the steppe and the high-potential cereal-growing regions of CWANA, these low-rainfall areas have very fragile agroecosystems. They are currently under threat from further degradation and erosion, caused by an increase in continuous barley cropping in response to burgeoning human populations. However, in these areas, drought-and/or cold-tolerant annual feed-legume crops could be introduced to augment feed resources and prevent soil degradation.

Therefore, ICARDA has developed new feed-legume breeding populations and supplied them to NARS in CWANA. These populations contain valuable levels of genetic diversity, allowing them to be grown in different environments. ICARDA also coordinates international trials that facilitate multilocation testing by

NARS. These enable national programs to identify promising lines that are well adapted to local conditions before releasing and distributing them to farmers. Many improved lines of common vetch (*Vicia sativa*), woolly-pod vetch (*V. villosa* subsp. *dasycarpa*), bitter vetch (*V. ervilia*), narbon vetch (*V. narbonensis*), Hungarian vetch (*V. panonica*), grass pea (*Lathyrus sativus*) and dwarf chickling (*L. cicera*) have been introduced in this way. Some of the major developments resulting from ICARDA's collaboration with NARS are highlighted below.

Extensive on-station and on-farm testing in Iraq, Jordan, Lebanon, and Syria has identified promising lines adapted to low-rainfall areas. On-farm trials have also demonstrated to farmers the benefits of using forage legumes in livestock production and the versatility of legumes for hay making, direct grazing, or harvesting at maturity for stored feed.

'Baraka,' a recently released variety of common vetch, is now widely used for direct grazing, hay making, and grain and straw production. Results from Iraq, Jordan, and Syria showed average daily weight gains of 90 g to 275 g in sheep grazing 'Baraka.' In Iraq, the milk production of ewes grazing 'Baraka' increased by 175 g/ewe per day on average.

The 'Jaboula' variety of dwarf chickling recently released in Lebanon was found to have been widely adopted by farmers in the El-Kasr area (average annual rainfall 200 mm). In addition, in an eight-hectare on-farm trial in Ebla, northern Syria (average annual rainfall 340 mm), an improved line of narbon vetch gave higher yields than farmers' traditional vetch varieties. The improved line gave an average grain yield of 1.5 t/ha and an average straw yield of 2.8 t/ha in the 2002/03 season. Also in 2003, the Syrian national program identified two lines of bitter vetch (sel#2790 and 2847) and one line of common vetch (sel#713), from ICARDA-supplied materials, for release as commercial varieties.


Sheep grazing 'Baraka,' a variety of common vetch released by NARS in Iraq, Jordan, and Lebanon.

In Rio Grande do Sul State in southern Brazil, improved lines of common vetch, woolly-pod vetch, and bitter vetch were tested, and highly adapted lines were selected from materials supplied by ICARDA over the last four years. Due to their high grain yield and ability to cover the soil surface, improved lines of bitter vetch were identified for use as a dual-purpose crop: for grain production and as green manure, which, when plowed in, helps to recycle nutrients in cereal/legume rotations. One line of common vetch (sel#3652) was also selected for on-farm trials, due to its earliness (68 days from emergence to flowering, and 117 days from emergence to maturity: 25 and 28 days earlier than the local variety, respectively). Forty-nine elite lines of woolly-pod vetch were tested and 13 selected for further evaluation. Results also confirmed the suitability of improved lines of dwarf chickling, which gave acceptable grain and herbage yields and exhibited early flowering and maturity.


An improved drought-tolerant line of narbon vetch (*Vicia narbonensis*), growing in a farmer's field in Ebla, Syria, where the average rainfall is 340 mm/year.

ICARDA is also developing improved germplasm for cold highland environments in Iran and Turkey. In Iran, the Dry Land Agricultural Research Institute (DARI) at Marageh has identified improved forage vetches and chicklings that are sufficiently cold tolerant to allow winter and early-spring planting while simultaneously giving high herbage and grain yields. Based on three years' results, one line of woolly-pod vetch (sel#2440) showed a higher degree of cold tolerance than the other legumes tested, and was recommended for release as a commercial variety. Seed multiplication enabled this variety to be distributed to farmers in Marageh, Sararood, and Gachsaran, for winter planting. Three lines of dwarf chickling (sel#500, 576, and 573) were selected for further testing (winter sowing) at Kohdasht, and nine high-potential lines (three each of woolly-pod vetch, bitter vetch and Hungarian vetch) were recommended for winter planting in Marageh, Ardebil, and Kordestan. Two improved lines of bitter vetch (sel#2561 and 2374) were also identified for varietal release and seed multiplication.

In Turkey, ICARDA is a partner in an extensive program to develop feed legumes for the country's highlands. Improved lines of common vetch, Hungarian vetch, woolly-pod vetch, and dwarf chickling have been tested. At Haymana and Ulus, improved cold tolerance was selected for in common vetch and Hungarian vetch.

Hungarian vetch (*Vicia panonica*) proved to be suitable for winter sowing in Marageh, Iran.

Improved forage quality is also an important objective in ICARDA's breeding program, which ensures that new varieties are acceptable to livestock. Therefore, efforts are focusing on antinutritional factors (ANFs) which are toxic to animals. For example, scientists have developed an improved line of common vetch (sel# 2604) with green seeds in which the concentration of the ANF γ-glutamyl-β-cyanoalanin is only 0.017% (as compared with 1% in wild types).

Underground vetch: a potential pasture and forage legume for dry areas in West Asia

Subterranean vetch (*Vicia sativa* subsp. *amphicarpa*) is native to disturbed grasslands in the Mediterranean basin, where heavy grazing, seasonal drought, and erosion act as strong selection forces. Subterranean vetch produces pods both above ground and 5 cm underground. Unlike subterranean clover (*Trifolium subterraneum*), which buries its seeds after flowering above ground, subterranean vetch flowers and forms pods beneath the soil's surface on underground stems. The aerial pods are produced after vegetative development ceases, while the underground pods are produced early in the plant's development. The aerial and underground pods serve two distinct functions; aerial pods increase seed dispersal and thus the establishment of new plants within suitable habitats, while underground pods increase the probability of plant survival under adverse conditions, such as drought and heavy grazing. These characteristics mean that this unusual vetch can survive in marginal areas with low rainfall (about 250 mm/year). As the herbage and pods it produces are nutritious, this vetch could prove very useful in rehabilitating degraded rangelands and increasing feed production for small ruminants.

ICARDA has assessed the herbage and seed productivity of underground vetch, as well as its ability to grow in rotation with barley in marginal low-rainfall areas, and its capacity to regenerate after heavy grazing. Scientists found that drier conditions favored earlier underground flowering, and led to the production of more underground pods than aerial pods. They also found that the grain yield of the 'Atlas' barley variety was around 2.0 t/ha when it followed underground vetch, but only 1.2 t/ha when it followed barley (Table 11). This clearly shows the yield advantages of practicing barley/underground vetch rotations. Also, the grazing of this vetch did not affect the productivity of the succeeding barley crop (Table 11).

To cope with the increasing feed requirements of CWANA's expanding livestock population, there is a need to introduce such pasture and forage legumes into the region's farming systems. Underground vetch could replace fallow, thereby allowing a ley-farming system to be established. In addition to high feed production, the forage legumes in the ley-farming system can have a tremendous positive impact on cereal production, as a result of symbiotic nitrogen fixation.

Table 11. Effect of grazing date on herbage yield of subterranean vetch in the establishment year at Tel Hadya, Syria, yield of the succeeding barley crop (as compared with barley after barley), vetch seed bank at the start and the end of the barley phase, and dry herbage yield of self-regenerated vetch after barley phase.

	Yield (kg/ha)					
	Grazing date			Without		
Parameter	Mid Feb	Mid March	Mid April	grazing	Barley	SEM
Vetch herbage yield (kg/ha) in establishment year	830	750	900	2020	-	57*
Vetch seed bank (kg/ha) before barley cropping	82	225	301	458	-	27*
Barley biological yield (kg/ha) [1]	4300	4200	4000	3900	3100	215*
Barley grain yield (kg/ha)	1966 (V/B)[2]	2035 (V/B)	1925 (V/B)	1900 (V/B)	1200 (B/B)	98*
Vetch seed bank (kg/ha) after barley cropping	75	205	290	400	-	97*
Vetch herbage yield (kg/ha): self regenerated after barley	3200	3900	3800	4000	-	320 (ns)

[1] Total biological yield above ground.
[2] Barley (B) after vetch (V).
* Significant at the 5% probability level; ns = non-significant.

Project 2.1. Integrated Pest Management in Cereal- and Food Legume-Based Cropping Systems in Dry Areas

An integrated pest management (IPM) approach is one in which farmers use the most efficient combination of options to protect a crop from pests and diseases. Employing a range of options, such as host-plant resistance, biological control, suitable agronomic practices, and habitat management allows chemical control to be reduced and strictly targeted, benefiting human health and the environment. In 2003, ICARDA identified new pathotypes of ascochyta blight affecting chickpea, documented the spread of tan spot disease in wheat, and used molecular markers to elucidate genetic diversity in two fungal pathogens affecting cereals. Researchers also identified new sources of resistance to faba bean diseases, and to Hessian fly in wheat. Research on *Bean leaf roll virus* led to new resistant genotypes of faba bean, as well as to a new, efficient method for screening both lentil and faba bean for resistance to the virus. Successes were also achieved in controlling Sunn pest in the field, using formulations of insect-killing fungi, and in developing a new IPM program to control *Orobanche*, a parasitic weed of faba bean.

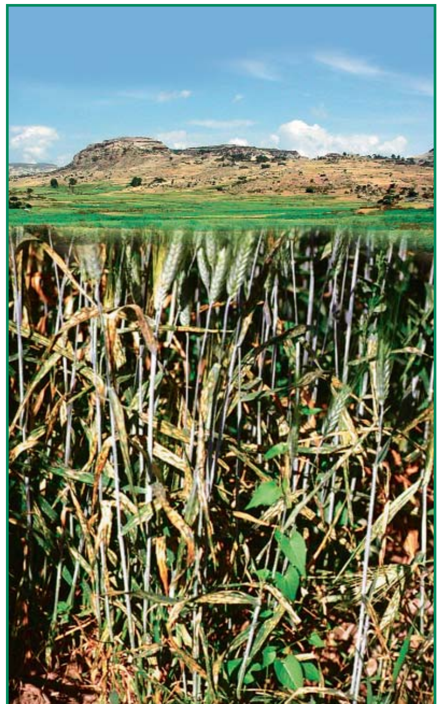
ICARDA's IPM strategy

Cereal and legume crops are the main food and feed crops in CWANA. However, their yields are low, variable, and unpredictable—often because of damage caused by disease and insect pests.

Chemicals and improved cultivars with major resistance genes are currently used to reduce losses. However, large-scale monocropping of genetically similar resistant cultivars has increased the risk of epidemics, when new virulent pathotypes/ biotypes overcome the resistance genes. ICARDA is studying the population genetics of pathogens, monitoring changes in pest populations, and searching for new sources of resistance for use in breeding programs. This will provide farmers with high-quality, improved and adapted seed in a cost-effective and sustainable manner.

Effective combinations of IPM options can be used by farmers to greatly reduce the losses caused by pests (defined here as including fungal and viral diseases and weeds, not just arthropods and nematodes). In addition, IPM can be used to introduce farmers to new varieties and improved cultural practices, thereby helping them overcome other, non-pest-related, production constraints. ICARDA is promoting technology transfer by establishing close relationships among researchers, extension specialists, farmers and other key stakeholders in the farming community. This has resulted in new IPM options better tailored to farmers' needs. Also, a greater number of farmers are now aware of the techniques available.

Increased occurrence of tan spot disease in CWANA



Lesions of tan spot on wheat leaves.

Tan spot in wheat, caused by the fungus *Pyrenophora tritici-repentis*, has been reported from most wheat-growing regions in Africa, North and South America, Asia, Australia, and Europe. The disease also affects other graminaceous plant species, such as rye and barley. Though all above-ground plant parts may be infected, tan spot mainly attacks the leaves—reducing photosynthetic surface, which results in smaller and lighter grains. Grain yield losses can reach 50% and grain quality may also be reduced.

Recently, the disease has been identified in wheat-growing areas in Syria—its first recorded occurrence in the country. Evidence of the presence of tan spot was provided by the observation of symptoms in the field, followed by isolation and identification of the pathogen. Two universal indicator cultivars, 'Glenlea' and 'Coulter,' developed necrotic symptoms typical of tan spot when inoculated with a single-spore culture of the pathogen. Lesions taken from 'Glenlea' and 'Coulter' and incubated in a moisture chamber produced abundant conidia of *Drechslera tritici-*

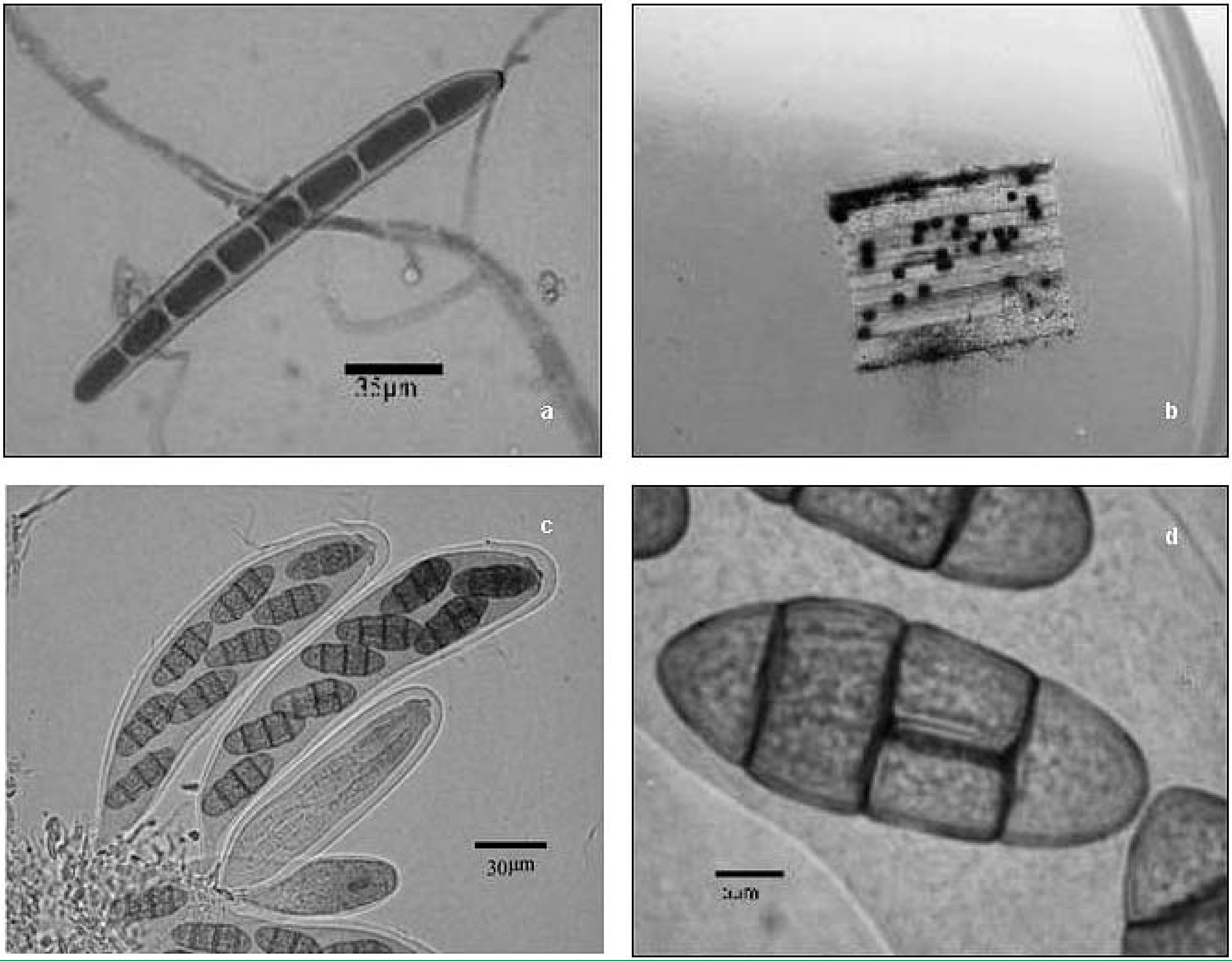


Fig. 10. Structure of the fungus causing tan spot disease in wheat in Syria: (a) conidium (asexual spore) borne on a conidiophore, (b) leaf fragment with sexual-spore-producing fruiting bodies (pseudothecia), (c) asci (sac-like structures that contain ascospores) that were released from the erupted pseudothecium, (d) ascospore.

repentis (the asexual form of the fungus). Evidence of the sexual cycle was found during detailed laboratory analyses (Fig. 10).

Recent studies by ICARDA, in collaboration with the University of Manitoba, Canada, also led to the identification and characterization of races of the pathogen from North Africa, the Near East, and the Caucasus region.

Over the past four years, surveys undertaken by ICARDA in Central Asia and the Caucasus have shown a rapid increase in the incidence of the disease. Increases in the occurrence of tan spot have been attributed to changing agronomic practices, such as an expansion of wheat cultivation, a shift from conventional to minimal tillage, the use of shorter rotations, continuous cultivation of spring and winter wheat, and the planting of highly susceptible cultivars. The disease is most severe in areas where wheat stubble is retained on the soil surface as a soil-conservation measure. The fungus grows saprophytically on the stubble, forming fruiting bodies (pseudothecia), which reproduce sexually and discharge ascospores during wet periods in the spring. Ascospores can be blown long distances, causing primary infection. Infected stubble may also act as a source of primary infection, as can infected seed, other grasses, and infected plants in nearby wheat fields. Wind-dispersed asexual fungal spores (conidia) are responsible for secondary infection cycles. Frequent rain and prolonged wetting of the foliage (during a particularly wet spring, for example) can increase the production of conidia and the rate of infection.

New pathotypes of *Ascochyta* blight

Ascochyta blight, caused by the fungus *Ascochyta rabiei*, damages

In 2003, ICARDA researchers identified new variants of *Ascochyta* blight, a serious fungal disease of chickpea.

chickpea crops around the world. The fungus reproduces both asexually and sexually (through the sexual form *Didymella rabiei*). Its spores are spread by rain splash and wind, and in the case of the sexually produced ascospores, can reach several kilometers. Three pathotypes of the *Ascochyta* pathogen were identified in the early 1990s: pathotypes I and II are reported from most growing areas, whereas the more aggressive pathotype III is not widely distributed. Because the fungus can reproduce sexually, new variants with a broad spectrum of virulence can be produced through sexual recombination. These could break down the resistance of chickpea lines developed earlier.

To assess the genetic variability and pathogenicity of the fungus, ICARDA researchers studied 30 isolates collected in 2002. From these, the DNA of three isolates from Syria and one from Iran was extracted, and variability at a hypervariable compound microsatellite locus (*ARMS1*) was examined. Analyses showed that, at this locus, the three isolates from Syria differed genetically from all three known pathotypes, suggesting that these isolates were new variants of the fungus.

This was confirmed by the results of pathogenicity tests in a plastic house at Tel Hadya, Syria, using five chickpea lines (ICC 12004, ICC 3996, ILC 194, ILC 5263, and ILC 5894) which exhibit characteristic reactions to pathotypes I, II, and III. The three isolates caused disease reactions that were different from those caused by the three known pathotypes and the Iranian isolate (Table 12). The Syrian isolates broke down the resistance of ICC 12004, ICC 3996 and FLIP 88-85, known to have an acceptable level of resistance to pathotype III. By contrast, they were less aggressive than pathotype III on ILC 194, ILC 5263, and ILC 5894. The Iranian isolate was less aggressive than the Syrian ones, causing a reaction which was similar to that caused by pathotype I.

These findings will strengthen efforts to pyramid genes for resistance to *Ascochyta* blight, and help to combat the disease more efficiently and effectively.

Table 12. Identification of three new variants of the *Ascochyta* blight fungus (*Ascochyta rabiei*) from Syria, based on the disease reaction (rating) of five chickpea lines. Disease rating: 1 = highly resistant and 9 = highly susceptible.

Chickpea line	Kaljebrine (Aleppo, Syria)	Tal Sandal (Idlib, Syria)	Skilbeieh (Hama, Syria)	Kermanshah (Iran)	Pathotype I	Pathotype II	Pathotype III
ICC 12004	8	8	7	2	2	6.5	4.5
ICC 3996	8	5	7	3	2	6.5	3.5
ILC 194	3.5	3.5	4	3	5	3	8
ILC 5263	4	2.5	4.5	4.5	2	3	8
ILC 5894	3	4	5	3	2	3.5	8

Understanding genetic variability of fungal pathogens for breeding resistant cereal cultivars

Knowledge of the amount and distribution of genetic variation in a plant pathogen provides information about gene flow and the speed with which pathotypes with new levels of virulence or resistance to fungicides will spread. Understanding the genetic variability of fungal diseases, both within and between cereal growing areas, allows for a faster, better targeted deployment of resistant barley and wheat cultivars.

Conventional assessments of pathogenic variability involve assays using differential cultivars. However, this technique has many disadvantages. Environmental conditions may be difficult to control, leading to overestimates of diversity and variability in the pathogen population. In addition, the scoring process is labor intensive and limits the number of fungal samples that can be processed. Information on both the geographical distribution of pathogens and the pathways by which they spread is also lacking, because the long distances traveled by the spores mean that many populations from a large geographic area would need to be assayed. Studies of fungal variability have therefore been limited to analyses of local fungal populations.

Researchers at ICARDA are now using molecular genetic markers to study the variation within and across the CWANA and Nile Valley and Red Sea regions in populations of the pathogens that cause widespread disease in barley and wheat.

Diversity in barley scald fungus

Barley scald, caused by the fungus *Rhynchosporium secalis*, occurs worldwide, and causes considerable yield losses. Host-plant resistance has been the major control method. However, the appearance of new scald pathotypes breaks down the host-plant resistance. To estimate the genetic relationships that exist among and within geographic populations, researchers used RAPD and AFLP markers to characterize *R. secalis* isolates. These isolates were collected at the end of the 1999 and 2000 growing seasons on infected barley leaves from 10 representative sites across CWANA. Using genomic DNA extracted from one isolate from each of the sites, a preliminary survey evaluated 70 random primers for their ability to prime PCR amplification. Total genetic diversity in the *R. secalis* populations was partitioned into five 'regions': (i) four populations from different sites in Syria and Lebanon; (ii) two from Turkey; (iii) two from Tunisia; (iv) one from Kyrgyzstan; and (v) one from Azerbaijan.

Genetic diversity was assessed within populations, and within and between regions. The greatest diversity (Fig. 11) was found to occur between regions. Genetic diversity between populations within a region was lower, ranging from 11% in Turkey to 19% in Syria and Lebanon, with 13% being an intermediate value for Tunisia.

The distribution of genetic diversity within populations differed between the regions, with the highest within-population diversity (38%) found at Eskesehir in Turkey. By contrast, the population from Kef, Tunisia exhibited no genetic differentiation. The within-population diversity in Syria, Lebanon, and Tunisia explained only 1.2% and 1.5% of the total variation, respectively.

These results show that genetic diversity between regions accounts for most of the total genetic diversity. The second largest contribution to total genetic diversity was made by variation between sites within a region. Genetic diversity within populations was very small, with the exception of the population from Aktep, Turkey.

Researchers at ICARDA are also studying polymorphism in *R. secalis*, as this too is related to pathotype diversity and stability. To date, the sexual stage (teleomorph) of *R. secalis* remains unidentified. However, this form is probably an important source of genetic variability in the fungus.

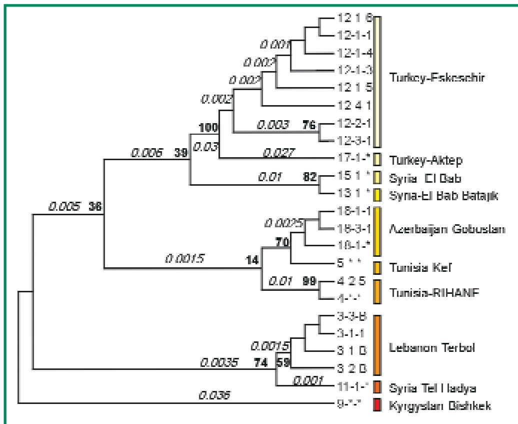


Figure 11. Genetic diversity between and within populations of *Rhynchosporium secalis*: a neighbor joining tree, based on Nei distances calculated from RAPD and AFLP genetic data. Numbers on branches represent genetic distances (italic) and the percentage of 100 bootstrap trials (bold). Samples from the same location, but which are genetically different, are represented as a single operational taxonomic unit (OTU). Asterisks (*) denote groups of samples from the same location that do not show any genetic differentiation. 'Tunisia-RIHANE': population found on variety 'Rihane' at Kef, Tunisia.

Diversity in septoria leaf blotch fungus

The septoria leaf blotch fungus (*Mycosphaerella graminicola*; anamorph: *Septoria tritici*) causes one of the most serious and widespread diseases of wheat, especially in areas with Mediterranean-type climates. Field observations, confirmed by pathogenicity testing, have shown that the pathogen displays 'host preference'—being more severe in durum wheat infected with isolates derived from durum, than in durum infected with isolates derived from bread wheat, and vice versa.

Using molecular markers, ICARDA studied host preference and genetic diversity within and among fungal populations on durum and bread wheat. Multi-dimensional scale analysis (MDS, Fig. 12) showed that the 138 isolates studied fell into three groups: (i) those derived from durum wheat, (ii) those derived from bread wheat, and (iii) those derived from both wheat types displaying a host preference. Other populations from the same region are grouped as illustrated by the *M. graminicola* populations found on durum and bread wheat in Tartous, Syria. It is possible that the mixed group results from sexual recombination (one parent originating from the durum pathogen population and the other from the bread wheat population). If so, this could provide the first clear genetic evidence for the existence of a sexual stage in Syria.

The highest level of genetic variation was found within populations explaining around 50% of the total variation found in the study. The variation among populations within each wheat species explained around 43% of the total variation; only 8% of the

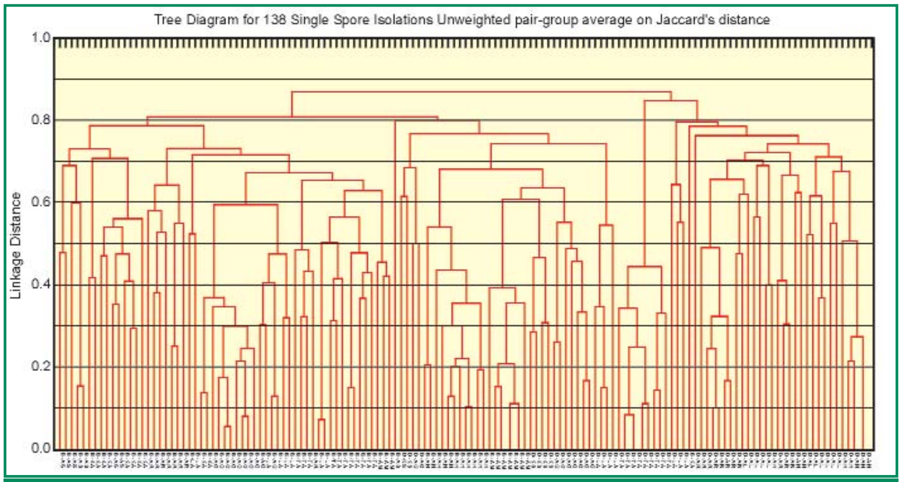


Figure 12. Genetic (AFLP-based) distances among 138 single-spore Syrian isolates of *Mycosphaerella graminicola*, the fungus causing septoria leaf blotch on wheat (results of multi-dimensional scale analysis, and use of unweighted pair-group average and Jaccard's distance).

total was explained by between wheat species variation.

Average gene diversity (AGD) was calculated based on Tajima's distance to each population. The AGD values ranged from 0.138 to 0.274 in bread wheat fields at Al-Ghab and Karakozak, respectively, and from 0.045 to 0.222 in durum wheat fields at Tartous and Al-Raqqa, respectively.

The level of genetic diversity within septoria leaf blotch pathogen populations in Syria is clear, being greater than that found among isolates from different locations. Use of AFLP markers confirmed the distinct host preference of *M. graminicola* populations for durum or bread wheat. The results also allude to the existence of the sexual stage, which explains the mixed group between durum and bread wheat pathogens.

New sources of resistance to faba bean diseases

Two of the most important diseases affecting faba bean (*Vicia faba*) are *Ascochyta* blight (*Didymella fabae*), also known as leaf and pod spot, and chocolate spot (*Botryotinia fabae*). Faba bean has little resistance to either of these pathogens. However, a local and international screening program organized by ICARDA over the last five years, and partly funded by the Australian Center for International Agricultural Research,

Ascochyta blight in faba bean.

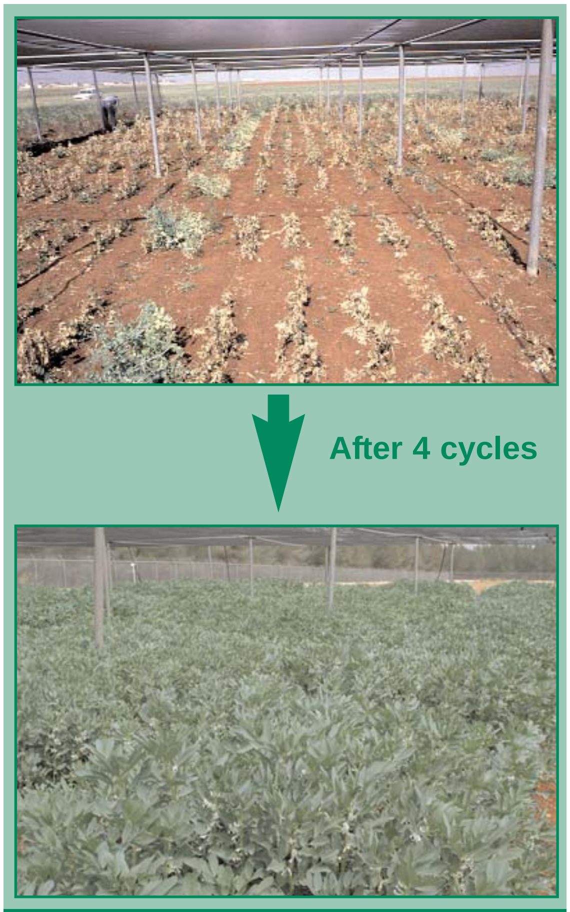
(ACIAR), has identified new sources of resistance to each, and in some cases, to both pathogens.

Between 1999 and 2003, around 1000 faba bean accessions and pure lines, as well as selections from 17 crosses, were screened for several cycles under artificial inoculation at ICARDA's Djableh Station on Syria's Mediterranean coast. The material tested was taken from ICARDA's genebank, and originated from 47 countries. At least 30 purified lines from Algeria, Egypt, Morocco, and Spain were screened, representing 92% of the total pure lines tested. A minimum of 30 accessions from China, Ecuador, Germany, Morocco, Syria, and Turkey were also screened, representing 65% of the total International Bean Lines tested. Four checks, 'ICARUS' (chocolate spot resistant), 'Rebaya 40' (chocolate spot susceptible), 'Ascot' (*Ascochyta* blight resistant), and 'Giza 4' (*Ascochyta* blight susceptible) were used as references.

Researchers identified 20 accessions resistant to *Ascochyta* blight and 29 resistant to chocolate spot. Six of these proved to have combined resistance to both pathogens. These sources are available from ICARDA and are currently being used in the Center's pre-breeding program, as well as in other breeding programs in WANA and Australia, to stabilize faba bean production.

New faba bean genotypes with resistance to *Bean leaf roll virus*

Bean leaf roll virus (BLRV), transmitted by aphids, is one of the most serious legume viruses affecting faba bean in the WANA region. Infected plants exhibit yellowing, leaf rolling, and significantly reduced pod-setting. Developing resistant cultivars is the most economical way to reduce losses caused by this virus. Over the last four years, progress has been made in identifying and selecting BLRV-resistant faba bean genotypes, in collaboration with NSW Agriculture, Australia, and with support from the Grains Research and Development Corporation (GRDC), Australia. Following four cycles of selection under high BLRV infection pressure in Syria, researchers identified high-yielding BLRV-resistant faba bean populations. Consequently, 15 highly BLRV-resistant faba bean lines from diverse origins were selected and deposited in ICARDA's genebank with new accession numbers. The resistance of these selections is based on their reaction to a BLRV isolate from Syria. It would be useful to test these selections in other countries where BLRV occurs. ICARDA is maintaining seed from these lines, and small quantities can be dispatched for evaluation upon request.



Selection and purification of faba bean lines with high levels of resistance to *Bean leaf roll virus*.

New sources of resistance to Hessian fly in wild relatives of wheat

Hessian fly causes serious wheat losses in North Africa and the north of Kazakhstan. In Morocco, for example, yield losses have been estimated to be about 35%. Researchers at ICARDA have recently found that the Syrian Hessian fly biotype is the most virulent in North Africa and Central Asia. Only the H25 and H26 resistance genes are effective against it. ICARDA has, therefore, been using this virulent biotype in its screening program to identify new sources of resistance.

A collection of 106 accessions of *Aegilops*, a wild relative of wheat, from the ICARDA durum wheat breeding program was evaluated at Tel Hadya by artificially infesting plants in a rearing room at 20ºC and 70% relative humidity. Seeds were sown in rows (around 20 seeds per row) in standard greenhouse flats (54 x 36 x 8 cm) containing a mixture of soil, vermiculite, and peat. Flats containing plants at the one-leaf stage were placed under a cheesecloth tent and infested with 50 mated female Hessian flies. These were allowed to lay eggs on the seedlings for two days. Plant reactions to larval feeding were determined 20 days after the eggs had hatched. Susceptible and resistant plants were separated on the basis of the symptoms of infection. Susceptible plants were stunted and dark green, whereas resistant plants were tall and remained light green. The larvae found within the stems of resistant plants were dead and had not developed beyond the first instar.

The study identified 24 accessions of *Aegilops* resistant to the Hessian fly biotype found in Syria. All exhibited dead first-instars, which indicated that antibiosis is the mechanism of resistance in these *Aegilops* accessions. The 24 resistant sources comprised 17 accessions of *Ae. ovata*, 4 of *Ae. ventricosa*, and 1 each of *Ae. triuncialis*, *Ae. longissima*, and *Ae. geniculata*. These resistant accessions will be used to broaden the genetic base of wheat for resistance to Hessian fly.

Controlling Sunn pest using insect-killing fungi

Sunn pest (*Eurygaster integriceps*) is a serious insect pest of wheat and barley in CWANA, causing both yield losses and deterioration of grain quality. Researchers at ICARDA are currently evaluating the long-term efficacy of preparations of an insect-killing fungus which is a natural pathogen of Sunn pest. Scientists developed granular formulations of the fungus, which were easy to use and persisted in the target environment for more than eight months.

Soil sampled from the hibernation sites sprayed with fungal formulations demonstrated that the persisting fungi induced Sunn pest mortality at rates of up to 46% after a 10-day exposure (Fig. 13). The fungal isolates used were

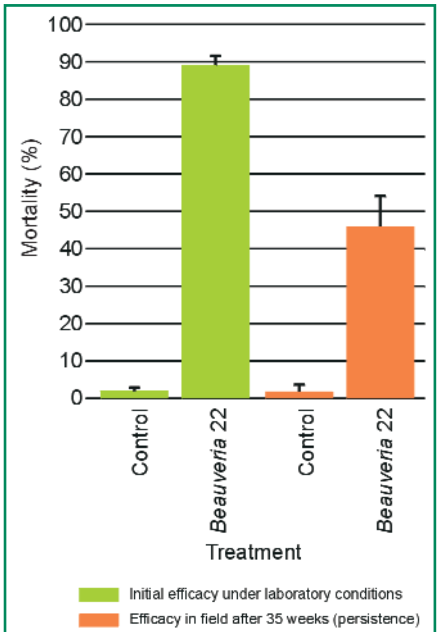


Fig. 13. Mortality of Sunn pest caused by applying a highly persistent granular formulation of a strain of insect-killing fungus (*Beauveria* 22).

effective because they are indigenous to the hibernating sites of Sunn pest, and adapted to that environment. Four of these highly virulent fungal isolates, and two commercially available fungi, are currently being field-tested using similar formulations. The most promising will be used to develop a fungal-based biopesticide, to target Sunn pest in its over-wintering habitat. It will also be tested in the spring around the edges of wheat fields to determine whether it can be used as a non-conventional control strategy.

Researchers also investigated the potential of ultra-low-volume formulations of fungi, and discovered that lethal doses of fungi could be delivered using this system. Laboratory testing of heat-tolerant fungal isolates is ongoing to determine an appropriate isolate for this strategy.

Using IPM in WANA to control *Orobanche*, a parasitic weed of faba bean

Faba bean productivity in WANA is low, mainly because of damage caused by such pests as *Orobanche* spp. (broomrape)—a parasitic weed that can cause yield losses ranging from 5 to 100%. The weed attaches to the roots of the host plant through strong haustoria, penetrating the tissues and absorbing the food gathered by the host plant for its own growth. *Orobanche* spreads from field to field through seed dispersal and, in particular, through the planting of contaminated seed.

A number of *Orobanche* species attack a wide range of cultivated plants. *Orobanche crenata*, for example, has been reported in 70-90% of faba bean fields in WANA. In Ethiopia, it is a new invader that could cause serious problems in the north. An awareness program is currently being run there as the first step in a comprehensive *Orobanche* management strategy. In Sudan, *O. crenata* was first reported on faba bean in the 2000/01 growing season in the north of the country. Major known crop hosts in Sudan include faba bean, pea, lentil and chickpea, and researchers there are trying to stop the weed from spreading into new areas. *Orobanche* has also recently become an important food-legume pest in Iran, spreading across large areas.

Over the past 30 years, researchers have generated, tested, and proposed different control measures. These include delayed sowing, hand pulling, use of tolerant varieties, use of the insect *Phytomyza orobanchia* as a biocontrol agent, and the cultivation of trap and catch crops. Chemical control with glyphosate herbicide and/or other chemicals is also an option, but there is a risk of crop phytotoxicity and *Orobanche* resistance. To date, these measures have not been very effective, partly because they are usually not well integrated into local production systems. A questionnaire survey of 240 faba bean growers in Egypt (Table 13) showed that growers frequently used crop rotation, late sowing in November, and hand-pulling to control *Orobanche*; few used chemical control methods or tolerant varieties. This is because farmers have little experience with herbicides and improved seed is difficult to obtain. An effective integrated *Orobanche* management strategy using a farming systems approach is, therefore, urgently needed.

ICARDA has established partnerships with key *Orobanche* IPM researchers. These include NARS in the Nile Valley and Red Sea (NVRS) region, the CGIAR Systemwide Program on IPM, and FAO. As part of this initiative to implement an effective *Orobanche*

Table 13. Farmers' adoption of different *Orobanche* control recommendations (percentage of farmers in each of four Governorates in Egypt): data from a survey of 240 faba bean growers during the 1999/00 cropping season.

	Governorate			
Control options	Kafr El-Sheikh	Dakahila	Menoufia	El-Fayoum
Practicing crop rotation: rice/faba bean	53	58		45
Avoiding sowing faba bean after faba bean	55	40	48	49
Late sowing in November	46	39	54	41
Hand-pulling of *Orobanche*	60	60	48	27
Using manure free of *Orobanche* seeds	42	30	59	4
Spraying with glyphosate herbicide	11		15	16
Soil solarization	2			
Using resistant cultivars	46		30	
Avoiding faba bean thrusting	41		59	50
Collecting and burning *Orobanche* spikes	56	42	5	

Source: El-Hassanein, El-Shirbini Hassanein, and Mamdouh Omar, ARC-Egypt.

IPM package, pilot sites have been established in Morocco and Egypt to test *Orobanche* control options in faba bean and chickpea. At these sites, researchers, extension specialists, farmers, and farmer-support groups are working together to identify knowledge gaps, research needs, and 'best-bet' IPM options.

In Egypt, production and pest problems were analyzed in consultation with farmers. 'Best bet' control options were then identified. In Morocco, an impact study using a sample of 250 farmers and 48 extension specialists revealed that:

- technology-transfer activities at the farmer level, using participatory approaches, were more efficient than large-scale, top-down diffusion techniques;
- farmers generally had a good understanding of chemical control possibilities; and
- carefully planned incentives may help the adoption of IPM techniques.

Participating farmers at the pilot sites reported high production increases (60% in faba bean and 11% in wheat), as compared with those obtained by traditional farmers. Both categories of farmers agreed that the pilot-site results have increased their confidence that faba bean cultivation could be profitable. In addition, the sites allowed around 300 farmers to be trained. The project has shown that training farmers in the basic principles of agroecology and formal experimentation can help them evaluate, modify (where necessary), and adopt IPM options. Now, the partners expect to scale out/scale up the IPM options for faba bean and significantly increase the area under the crop.

***Orobanche* infestation in faba bean.**

Given these promising results, ICARDA and representatives of CWANA countries have begun to develop a new, regional IPM strategy. This will enable farmers reduce *Orobanche* infestation significantly in the medium term. One such step was an FAO-sponsored technical meeting organized by ICARDA and held in Rabat, Morocco, in April 2003, at which participants agreed that action was needed, both to prevent the further spread of *Orobanche* and to better exploit the biological control opportunities presented by *Phytomyza* spp. They also identified the need for an *Orobanche*-control training program for technical field personnel and farmers.

To strengthen links between different stakeholders, and to make a more effective use of current knowledge and control methods, a three-day workshop on *Orobanche* IPM was also held in September 2003, in El-Fayoum, Egypt. The group developed a regional action plan to be implemented through an FAO-sponsored Technical Cooperation Project (TCP) which will begin in 2004. This will focus on training and the introduction of *Orobanche* IPM to a large number of farmers, through farmer field schools. Workshop participants identified the need for strategic research on parasitic-weed seed ecology in general, as well as on strain variability, biological control options, and new sources of resistance. Partners with relevant expertise who will take the lead on specific topics were identified at the workshop. FAO requested ICARDA to manage the TCP, and develop a comprehensive regional IPM program on *Orobanche*—in close partnership with NARS—to ensure that IPM activities are self-sustaining.

Project 2.2. Agronomic Management of Cropping Systems for Sustainable Crop Production in Dry Areas

In its work on sustainable cropping systems, ICARDA is addressing the key issues of fertilizer use, integrated soil fertility, and soil degradation. In 2003, results from a long-term trial in Syria showed that cereal crop yields were not lower under shallow, conservation tillage than under deep, conventional tillage. Since conservation tillage uses less energy, farmers save on gasoline costs while not experiencing any drop in productivity. The trial also included legume rotations and straw-management and compost addition options—which can restore degraded soils. Researchers discovered that both conservation tillage and compost addition led to a buildup of fertility in the upper soil layers through increased carbon sequestration.

Improving soils through crop rotations, conservation tillage, straw management, and compost use

Rapid intensification of arable farming in West Asia and North Africa (WANA) is causing soil fertility problems and high rates of land degradation. Previously, crop/fallow systems helped to ensure acceptable yields in dry areas by allowing soils to recover. But, farmers can no longer leave land unused for more than 14 months, so they have switched to continuous cereal cropping in all but the driest cropping areas (<250 mm rainfall/year). Fertilizer use is now common. Tractor use, and the practice of plowing to a depth of 20-30 cm every year with disc or moldboard plows, have also spread to much of the region in the last 40 years. Scientists are concerned that such deep plowing is not sustainable in the long term, as it breaks down soil organic matter (SOM). The loss of SOM, and thus soil carbon, reduces yields, as well as soil fertility, and promotes soil erosion, water pollution, and the greenhouse effect.

Tillage treatments in the long-term trial at ICARDA.

Since the mid-1980s, ICARDA has been working to identify more sustainable cropping systems, using long-term trials. One such trial was set up in 1996 at Tel Hadya, Syria, on an alkaline, very fine clay soil that is representative of many soils in WANA. This trial will run until at least 2008 allowing researchers to examine the influence of crop rotations, tillage and crop-residue management options both with and without compost addition on soil properties and crop yields.

Cereal/legume rotations have been included in the trial because they generally yield only about 15% less cereal than the traditional fallow system—unlike continuous cereal cropping, which yields 55% less. Moreover, the legumes grown provide feed for livestock, while the rotations reduce the buildup of disease, and can increase levels of soil organic carbon, thereby helping to mitigate global warming. In the trial, barley (planted in years 1, 3, 5, etc.) was rotated with an 80:20 mixture of vetch (*Vicia sativa*) and oats (in years 2, 4, 6 etc.). The vetch and oat mixture was cut for hay to feed livestock.

The trial also compares two tillage treatments:

- Conventional tillage—deep plowing (to a depth of 25-30 cm, using a moldboard plow) and shallow plowing (to a depth of 10-15 cm) after cereals.
- Conservation tillage—shallow plowing (to a depth of 10-15 cm), using a 'ducksfoot' cultivator after legumes.

Different straw management and compost treatments were also used in the trial; these are given in Table 14, along with the results for barley yield to date. Average barley yields over the period 1998-2003 were significantly greater in the compost treatments than in the no-compost treatments. However, because of year-to-year differences in the weather conditions, the differences between these treatments were not significant in any one year. No significant interaction was found between tillage and straw-management/compost treatments, and no overall significant difference was found in average barley yields (1998-2003) between the tillage treatments. This means that conservation tillage offers farmers substantial economic benefits over conventional tillage, because it uses less energy (12-18

Table 14. Mean barley grain yield (t/ha) in rotation with a vetch and oat mixture in a long-term trial at Tel Hadya, Syria, 1998-2003[1].

Tillage method (type of cultivator)	Straw-management/compost treatments: (a) Straw and stubble burned	b) Stubble incorporated	(c) Stubble and chopped straw incorporated	Treatment (c) + compost every 2 years[2]	Treatment (c) + compost every 4 years[2]	Mean
Conservation ('ducksfoot' cultivator)	3.936	3.929	4.121	4.351	4.406	4.148
Conventional (moldboard plow)	4.227	4.204	4.142	4.315	4.520	4.282
Mean	4.081	4.066	4.131	4.333	4.463	

[1] Rainfall ranged from a minimum of 260 mm (in the 1999/00 growing season) to a maximum of 492 mm (in the 2002/03 season).
[2] Compost (10t/ha dry matter) was plowed into the soil.

liters of gasoline/ha) without reducing barley yields.

After seven years, some treatments had clearly affected soil properties, especially SOM levels. For example, SOM concentrations in the top 30 cm of soil were significantly greater under conservation tillage than under conventional tillage (36.7 t/ha and 31.4 t/ha, respectively). Differences were greatest in the top 10 cm of the soil: 18.2 t/ha for conservation tillage and 12.7 t/ha for conventional tillage. In fact, SOM values in the top 15 cm of soil were always greatest for conservation tillage, irrespective of straw-management treatments (Fig. 14). However, at a depth of 20-30 cm, SOM values were slightly higher in conventional tillage (8.5 t/ha) than in conservation tillage. (7.6 t/ha), partly because the moldboard plow distributes SOM uniformly throughout the top 30 cm of the soil. Because of this, in the conventional tillage treatments, SOM values were uniform throughout the soil profile (about 1.0%), except in the case of the two-yearly compost-addition treatments, where they were higher (1.25-1.5%).

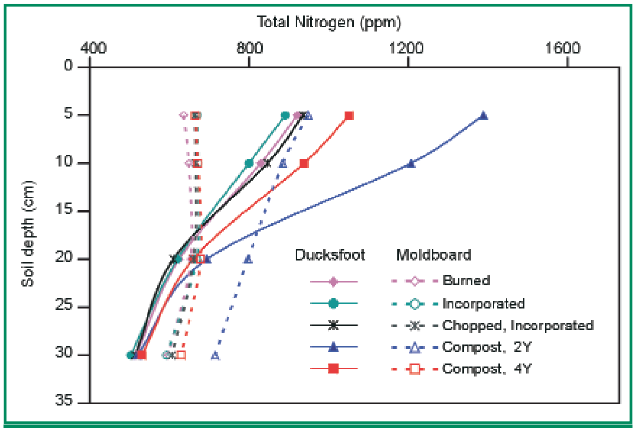


Fig. 15. Total soil nitrogen in different tillage and straw-management/compost treatments in a seven-year trial at Tel Hadya, Syria.

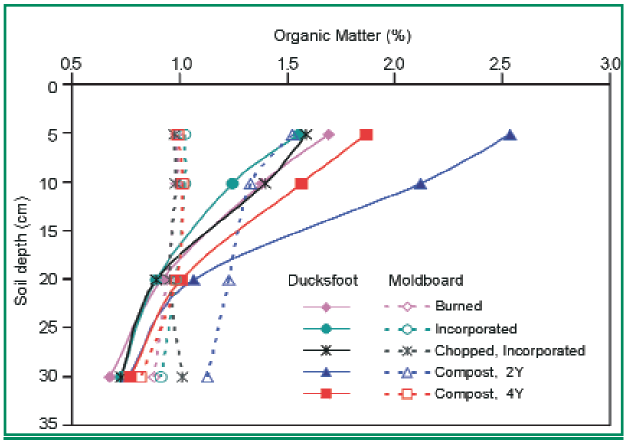


Fig. 14. Soil organic matter concentrations in different tillage and straw-management treatments in a seven-year trial at Tel Hadya, Syria. A 'ducksfoot' cultivator was used for shallow plowing in conservation tillage, and a moldboard plow was used for deep plowing in conventional tillage. Compost was added every 2 or 4 years in two treatments in which stubble and chopped straw had also been incorporated into the soil.

Compost addition markedly increased average SOM levels. The highest overall values were observed when compost was added every two years (2.0-2.5%), followed by compost addition every four years (1.6-1.9%). Thus, adding compost every two years led to SOM contents of 41.4 t/ha (under conservation tillage) and 38.7 t/ha (under conventional tillage) in the top 30 cm of the soil. When it was added every four years these figures dropped to 34.9 t/ha and 28.9 t/ha, respectively. In the compost-addition treatments, SOM distribution within the upper soil layers was similar to that in the tillage treatments (Fig. 14). The straw-management treatments all had similar effects on SOM distribution.

Values for total nitrogen followed the same pattern as SOM (Fig. 15). More soil nitrogen was found after conservation tillage than after conventional tillage in the top 15 cm of soil. In the same soil layer, compost addition also resulted in markedly more nitrogen in the majority of cases.

In the case of soil mineral nitrogen, the sum of both nitrate and ammonium fractions, the effects of treatments were less clear than they were for SOM and total nitrogen. This was true for both mineral nitrogen content and nitrogen distribution throughout the soil profile. But, conservation tillage did tend to lead to higher mineral nitrogen values in the top soil layer (0-15 cm) and lower values at depth. Effects of the treatments on soil compaction (bulk density) and soil moisture content were less consistent. Other treatment effects were minor, but are likely to be accentuated with time.

The improvements seen in SOM and nitrogen levels under conservation tillage indicate a buildup of soil fertility. By the end of the trial in 2008, it is expected that these positive impacts will be accentuated and will lead to higher yields.

Project 2.3. Improvement of Sown Pasture and Forage Production for Livestock Feed in Dry Areas

Introducing forage legumes into cereal crop rotations can have a number of benefits. In addition to providing nutritious fodder, soil fertility is improved and cereal yields are maintained, resulting in a more sustainable production system. These benefits can be used to increase the income of resource-poor farmers and to rehabilitate heavily overgrazed, degraded rangeland in CWANA. Recent results of a nine-year study demonstrated that wheat grown in rotation with medic and vetch produced 40% more grain and straw than continuously cropped wheat. The nutritious grazing provided by the wheat/legume rotations also allowed lamb meat, milk and wool to be produced. Farmers' returns from those systems were, therefore, two to three times higher than those obtained only from continuous wheat cropping.

Cereal/legume rotations: improving the incomes of crop-livestock farmers

About 24 million crop–livestock farmers in the dry areas of Central and West Asia and North Africa (CWANA) depend on rainfed agriculture for their livelihoods. Livestock, especially sheep and goats, are important to these farmers because they provide meat, milk, wool, and manure for use as fertilizer or fuel. About 40 years ago, the region's sheep and goats obtained 60–80% of their feed from grazing native rangelands. However, increasing population pressure and demand for livestock products are leading to overgrazing, rangeland deterioration, deforestation, and expanding desert margins. Today, the rangelands can only provide 10-15% of the feed needs of the growing sheep and goat populations. Shortage of livestock feed is, therefore, a major problem faced by poor crop–livestock farmers.

Growing feed legumes after cereal, instead of leaving the land fallow, provides feed for livestock and improves the soil nutrient status.

To meet the increasing feed needs of their livestock, most farmers have replaced traditional cereal/fallow rotations with continuous cereal cultivation, which eventually reduces cereal yields and soil fertility. To reverse this trend, ICARDA and its national partners in the region are assessing the benefits of growing different feed legumes, such as medic (*Medicago* spp.) and common vetch (*Vicia sativa*), in rotation with barley, wheat and other cereals. This will allow researchers to develop appropriate cropping systems to replace continuous cereal cropping and reduce the grazing pressure on the rangelands.

Results from a nine-year rotation study in Syria conducted in collaboration with the Syrian National Program showed that both the grain and straw yields of wheat grown after medic or vetch (both of which were used for grazing) were more than 40% higher than those of continuously cropped wheat (Fig. 16). There

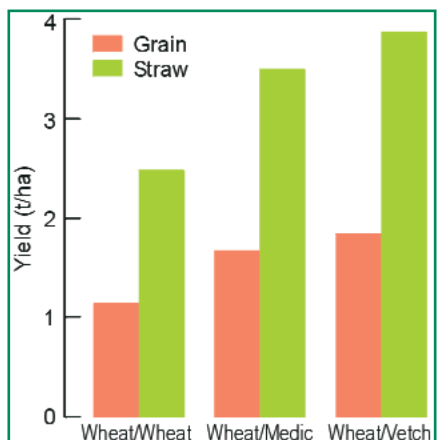


Fig. 16. Wheat grain and straw yields from different wheat-based rotations in Kamishly, northeast Syria, from 1994 to 2002.

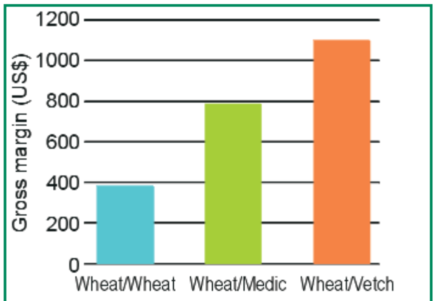


Fig. 17. Gross margins from different wheat-based rotations in Kamishly, northeast Syria. Values are based on average yields of wheat grain and straw, live-weight gain of lambs grazing vetch, and milk off-take and wool production of ewes grazing medic after wheat, from 1994 to 2002.

were also indications that rotating wheat with legumes could improve the soil's nutrient status. For example, soil organic carbon, total nitrogen, and available phosphorus levels in wheat/vetch rotations were about 2%, 9%, and 3% greater than in wheat/wheat rotations. Lambs grazing vetch grown after wheat gained 144 g per day, resulting in an average live-weight gain of 334 kg/ha. Similarly, the milk off-take and wool production of lactating Awassi ewes grazing medic pasture grown after wheat averaged 614 and 22.7 kg/ha, respectively. Preliminary economic analyses showed that gross margins from the wheat/medic and wheat/vetch rotations were about two to three times higher than that of the wheat/wheat rotation (Fig. 17). The results suggest that the incomes of crop–livestock farmers in the mixed rainfed production systems in the dry areas of CWANA, as well as the soil resource base, could be improved by promoting appropriate cereal/forage-legume rotation technologies.

Project 2.4. Rehabilitation and Improved Management of Pastures and Rangeland in Dry Areas

In many dry areas of CWANA, increasing population pressures are degrading the region's natural resource base and undermining the long-term well-being of the region. ICARDA and its partners have been addressing the problem of agricultural encroachment and overgrazing in several countries. In 2003, ICARDA continued working to restore the large areas of Syria's rangeland that have been degraded by failed attempts to grow barley. The research focused on introducing mixtures of suitable perennial species, to provide stable forage for the country's growing livestock population and to combat soil degradation. Results have been promising, with some species of saltbush achieving a survival rate close to 90%. Barley–saltbush intercropping trials suggest that not only will extra forage be produced and wind erosion reduced, the grain yield of the associated barley crop will also be increased. The project also addressed issues of technology transfer and farmer participation in 2003 through a successful field day held in Khanasser.

Restoring the rangelands of the Syrian steppe

In CWANA, small-ruminant flocks are used for subsistence, income generation, and risk mitigation, especially drought survival. But many impoverished households are threatened with further loss of income, because the feed resources on which their livestock depend are degrading. Feed resources vary spatially and temporally, and herders manage their flocks accordingly. Besides supplying forage during the spring growing season, rangelands in the semi-arid zone and in the margins of the rainfed-cropping zone also provide low-cost forage during other critical seasons, such as late summer when cereal-crop stubble is not available. Rangeland shrubs also provide households with fuel, and are harvested in significant numbers. Rangeland vegetation covers such vast areas of CWANA that reversing their degradation and increasing range-plant biomass could help to reduce global warming by enhancing carbon sequestration. ICARDA's mission, therefore, is to improve the welfare of rangeland inhabitants in the dry areas of developing countries, while preserving and enhancing rangeland ecosystems.

Much of Syria's rangeland has been damaged by attempts to cultivate barley in areas where the mean annual rainfall is less than

Reseeding severely degraded rangeland with the "pitter-seeder," one of the technologies tested at three locations in Syria.

200 mm. Now abandoned, these areas have a low vegetative cover of annual weeds, which leaves the land exposed to erosion. Syria now prohibits cultivation within zones where rainfall is less than 200 mm, but the damaged rangelands need to be rehabilitated.

Perennial vegetation, made up of a suitable mix of species, can produce as much, or possibly even more, forage biomass as a barley crop with the added benefit of less year-to-year variation. But, establishing productive and protective forage vegetation may require a combination of direct seeding and transplanting. ICARDA conducted research into the re-establishment of rangeland vegetation on abandoned marginal land.

Three 6-hectare sites were selected as representative of the three provinces of Aleppo, Hama, and Homs. The sites are located on the Syrian steppe, where barley cultivation was practiced until 1995. Two separate experiments were conducted at each site:

- **Transplanting experiment—** Seedlings of 18 different shrub and grass species (Table 15) were selected and transplanted in January 2003 to determine which were most suitable for use in rehabilitating the range. At the same time, water-harvesting structures were constructed on half the area of each replication, to determine whether water harvesting would help establishment. Survival and vigor of seedlings was observed during the first season.
- **Direct-seeding experiment—** Saltbush (*Atriplex* spp.) is frequently transplanted onto abandoned farmland by the government to restore forage production and protect the soil. However, little protective vegetation grows between the shrub rows. Researchers established saltbush rows, and planted rangeland species between them using two methods: (i) broadcasting seed and (ii) seeding in small pits, which were designed to catch and hold precipitation on the site.

The vegetation native to the three sites was also recorded and classified. Native plant species were identified and categorized according to their abundance at each site: 'dominant,' 'less dominant,' 'few,' and 'rare.' Thirty-three, 40 and 49 species were recorded at the Aleppo, Hama, and Homs sites, respectively. The plant communities of both the Aleppo and Hama sites were similar, with the grass, *Poa bulbosa*, being the dominant species. However, the succulent herb, *Aizoon hispanicum*, dominated the Homs site, an indication of saline soil. Many of the species found on the three sites are either not very palatable to sheep or can only be grazed when dry (i.e. *Anabasis* sp. or *Achillea* sp.). Many of the species present are classified as medicinal plants.

In early June, the beginning of the dry season, the amount of residual dry matter from native vegetation that had grown spontaneously between the rows in spring was estimated by clipping and weighing. This was an indication of site productivity. The estimates of dry matter obtained varied considerably, both between the three sites and within each site. Average dry matter (± standard error) was highest for the Hama steppe (797±192 kg/ha), followed by the Aleppo and Homs steppe sites (578±382 kg/ha and 362±367 kg/ha, respectively).

Transplanted species on the three sites were scored for vigor in June

Table 15. Vigor and survival percentage of transplanted plants of different drought-tolerant species with the potential to provide forage and rehabilitate degraded land, at three sites in Syria.

Species	Origin	Vigor[1]			Survival (%)		
		Homs	Hama	Aleppo	Homs	Hama	Aleppo
Artemisia herba-alba	Syria (Ain Zarqa)	4.0	8.0	6.5	95	99	87
Atriplex halimus-halimus	Spain (Alhama)	7.5	6.8	5.8	100	97	87
Atriplex lentiformis	USA (Maricopa)	8.0	7.5	6.5	98	96	93
Atriplex leucoclada	Syria	7.5	7.8	7.0	99	91	75
Atriplex torreyi	USA	6.5	7.3	7.0	94	96	97
Oryzopsis miliacea	Syria (Tel Hadya)	6.0	8.0	6.0	98	94	95
Salsola orientalis	Uzbekistan (Samarkand)	4.5	5.5	4.5	60	76	72
Agropyron elongatum	USA	5.5	7.3	5.8	97	97	94
Phalaris tuberose	Syria	5.5	6.8	3.3	95	97	88
Festuca elatior	Morocco	4.5	6.0	4.0	94	99	94
Dactylis glomerata	Syria	6.0	7.5	4.0	78	95	95
Atriplex halimus	Tunisia	8.0	7.0	5.8	97	95	87
Atriplex halimus	Syria (Deir-Ezoor)	3.5	8.0	6.5	46	99	98
Atriplex canescens	USA	4.5	8.5	6.5	76	95	94
Salsola vermiculata	Syria (Maragha)	7.5	7.0	6.5	97	96	97
Haloxylon aphyllum	Syria (Aleppo Steppe)	6.0	7.5	6.0	95	96	83
Atriplex halimus (prostrate)	Syria (Aleppo Steppe)	7.5	7.8	6.3	87	94	98
Atriplex halimus (erect)	Syria (Aleppo Steppe)	7.5	7.5	7.5	95	100	95

1. Assessed using a scale of 1 to 10; 1 = least vigorous, 10 = most vigorous.

2003 using a scale of 1 to 10 (Table 15). The plants displayed good vigor and very little dieback. The highest scores for plant vigor were obtained for several species of saltbush, which are adapted to the Syrian steppe. In June 2003, the number of seedlings from each species was counted, to assess seedling survival rates. Shrubs overall had a success rate close to 90%, although *Salsola orientalis* from Uzbekistan had the lowest survival rate (Table 15).

Farmers from Aleppo, along with researchers from the Syrian national Program and ICARDA, evaluate the performance of saltbush intercropping in Khanasser Valley.

Intercropping barley between forage-shrub hedgerows

Barley is the dominant crop in CWANA's low-rainfall areas despite the nutrient-poor soils and low productivity. A new cropping system is needed to produce high-quality fodder and protect the soil without jeopardizing grain production. To this end, ICARDA evaluated the performance of cereal crops grown in combination with widely spaced hedgerows of drought-tolerant fodder shrubs (saltbush) in Syria. The study aimed to determine whether both the quantity and quality of the feed available to small ruminants grazing barley stubble in the marginal areas of the Aleppo steppe could be improved by using this type of intercropping system.

Barley grain yield was measured at only two sites, as farmers in the other sites planted different crops between the saltbush rows. In Kurbatieh, grain yields were similar in the intercropped and monocropped treatments (946 kg/ha and 968 kg/ha, respectively). In Rashadyeh, however, grain production was much greater in the intercropped treatment (988 kg/ha compared with 620 kg/ha). Some farmers planted cumin, wheat, or vetch between saltbush, as an alternative to barley, depending on the market for, and price of, the crop.

During the spring of 2003, a field day was held in Khanasser, Syria so that researchers and farmers could jointly evaluate the intercropping technology. The event allowed farmers to interact with scientists and assess the various technological and management options. The farmers agreed that saltbush has multiple benefits—being nutritious and palatable to sheep, providing green forage in the dry season, and protecting the soil from wind erosion. Not only does it reduce the amount of feed needed, it also increases soil fertility and, as an added benefit, grows on salty soils. However, farmers also identified some disadvantages, in that it increases the number of field rats and the amount of weeds.

The meeting also identified obstacles that limit the expansion of saltbush in the region. These include (i) the cost of cultivation, (ii) the cost of protecting seedlings from grazing animals before they have become established, (iii) the fact that farmers have no experience of growing saltbush, (iv) a lack of information as to where seedlings can be obtained, and (v) a lack of cash to cover cultivation costs. That saltbush is planted on a small scale, proportional to the owner's flock size, was also seen to be a factor likely to limit the spread of the shrub, as was the fact that it cannot be used as a cash crop by farmers with no sheep. Farmers were reluctant to apply the new technology without subsidies to help cover the establishment costs, and expressed a need for technical advice. Based upon these responses from farmers, ICARDA will provide technical information to extension agents to allow them to demonstrate the benefits of intercropping. Government programs and projects in the area are advised to consider providing assistance to farmers for shrub planting, including establishment subsidies.

Of the more than 9000 saltbush seedlings planted during the last five years, none have been removed by farmers. This indicates that the shrubs will be maintained for a long time, if farmers are provided with assistance during establishment.

Project 2.5. Improvement of Small-Ruminant Production in Dry Areas

ICARDA is helping small-scale farmers in CWANA cope with the challenges facing their traditional production systems. In 2003, ICARDA researchers tested a new early-lambing system in Uzbekistan which allowed ewes and lambs to graze in rich spring pastures. As a result, ewes lost less weight between mating and lambing, recovered faster from the effects of lactation, and maintained better condition in consecutive lambings. Fertility rates were higher than in the traditional system, and lambs born early could be sold early, when market prices were high and supply low. In a separate study in Syria, researchers also surveyed 241 lamb fattening systems and characterized these profitable enterprises, which have recently developed in response to an increased demand for lamb. They also identified feed-supply and lamb-health problems as production constraints, and noted that lack of credit prevented resource-poor farmers from setting up such enterprises.

New management strategies for winter feeding of Karakul sheep in Uzbekistan

Sheep production in most Central Asian countries is constrained by winter-feeding costs. In the region's traditional Karakul sheep production system, mating and lambing occur in October and March, respectively, and pregnancy coincides with low range productivity in the winter. As a result, unless sufficient stored feed is available, ewe and lamb mortality increases. The system was widely implemented during the Soviet Union period when production schemes ensured that sufficient feedstocks were available in the winter. However, the system was disrupted after the dissolution of the Soviet Union.

New production strategies are therefore required to target available markets and cope with feeding costs. An option identified by ICARDA researchers is to change the lambing season from March to January, which allows farmers to benefit from the spring growth of rangeland grasses as well as the high demand for lambs in June, when supply is at its lowest. Early lambing also allows ewe lambs that weigh enough to be mated early, thereby enhancing a ewe's production over its lifetime.

To assess the impact of improved production schedules, scientists from ICARDA and the Karakul Sheep Breeding and Desert Ecology Research Institute in Samarkand, Uzbekistan, conducted research at the Gazgan pedigree farm, located in the foothills of a semi-desert range, in the Nurata District of Uzbekistan's Navoyi Province. A total of 305 Karakul ewes, divided into three mating groups, were assessed. The groups lambed in January ('winter'), February ('early spring'), and March ('spring'/control) of 2001. The work was then repeated in 2002, using the same lambing schedules and ewes, but dividing them into two sub-categories: (i) ewes that had suckled their lambs in 2001 and (ii) ewes that had their lambs slaughtered at lambing in 2001, known as Mary ewes.

In 2001, all the ewes were given additional feed during the last 45 days of pregnancy. In 2002, the winter-lambing and early-spring-lambing ewes also received additional feed during the last 45 days of pregnancy; the spring/control group only required 40 days of additional feed, as grazing was available on the range by March (350 kg DM/ha). However, the winter-lambing group also required additional feed for 15 days after lambing, because range biomass was low in February (150 DM kg/ha). The extra feed given to winter-lambing ewes meant that feed costs for this group were 33-50% higher than those in the spring/control group.

In 2001, the percentages of lambs born per ewe that lambed in winter, early spring, and spring were similar (104%, 103%, and 100%, respectively). However, in 2002, a more detailed review of reproductive performance (Table 16) showed that those ewes that

Table 16. Reproductive performance of Karakul ewes in 2002, in relation to their lambing period and lactation condition in 2001.

Lambing period in 2001	Ewe condition in 2001	Lambing period in 2002	Number of ewes exposed	Number of ewes that lambed	Fertility (%)	Prolificacy (%)
Winter	Suckling	Winter	73	66	90.4	104.5
	Mary*		58	54	93.1	103.7
	Total		**131**	**120**	**91.6**	**104.2**
Early spring	Suckling	Early spring	54	48	88.9	104.2
	Mary		37	34	91.9	102.9
	Total		**91**	**82**	**90.1**	**103.7**
Spring	Suckling	Spring	38	33	86.8	103.0
	Mary		24	22	91.7	100.0
	Total		**62**	**55**	**88.7**	**101.8**

***Mary ewes are those whose lambs were slaughtered for pelts soon after they were born.**

had lambed in early spring and spring of 2001, and that then suckled their offspring, had lower fertility levels (88.9% and 86.8%, respectively) than winter-lambed ewes in the same category (90.4%). By contrast, the 2002 fertility levels of Mary ewes differed only minimally between the three lambing-period groups. Prolificacy (a measure of litter size) was not affected by lambing period.

Weight changes in the ewes from mating to lambing were observed in 2001 (Fig. 18). Three facts emerged from the results:

(1) The drop in weight from mating to lambing was less accentuated in early-lambing ewes. The body-weight drop in ewes that lambed in January, February, and March (i.e. those mated in August, September, and October) averaged 6.6, 9.2, and 9.7 kg, respectively.

(2) Ewes that lambed early (in January and February) recovered faster than those lambing in the traditional period (March), and escaped the effects of lactation during the summer, as they had already reached the heavier post-lambing weights by June. This was reflected in higher fertility rates in the next mating season (Table 16).

(3) The number of months the ewes weighed below 40 kg was greater in ewes lambing in March (4 months) as opposed to ewes lambing in January (3 months). Note that this period, when ewes' weights are low after lambing, coincides with the extra requirements of lactation and the growth of ephemerals in spring pastures that starts in March.

Ewes that lambed in early 2001 and suckled their lambs started off with a high weight (Fig. 19a), and in 2002 their weights followed a similar trend to that observed in 2001. Ewes that had lambed in March 2001, however, started with lower weights and were severely affected by lactation and the low availability of forage in the range in the summer of 2001, which made it difficult for them to recover (Fig. 19a). By contrast, the weights of non-lactating Mary ewes (Fig. 19b), were similar to those in 2001 (Fig. 18), even for ewes in the March-lambing group.

Lamb growth followed similar patterns in both years, irrespective of the condition of the ewes (Fig. 20). By June, lambs born later in the year had reached only 70% of the weight of January-born lambs, in spite of the good grazing available in spring. By June, January-born lambs were 5.3 kg heavier than those born in February and 9.5 kg heavier than those born in March.

The results of this work suggest that early lambing, in winter and early spring, has advantages over traditional Karakul spring lambing under current management conditions in Nurata. Early-lambed ewes recovered faster from lactation, and lamb growth benefited directly from grazing green vegetation on the range. Reproduction was improved, and ewe-lambs could be mated in their first year of life. In addition, the long-term reproduction performance of lactating ewes was not affected as they maintained better condition in consecutive

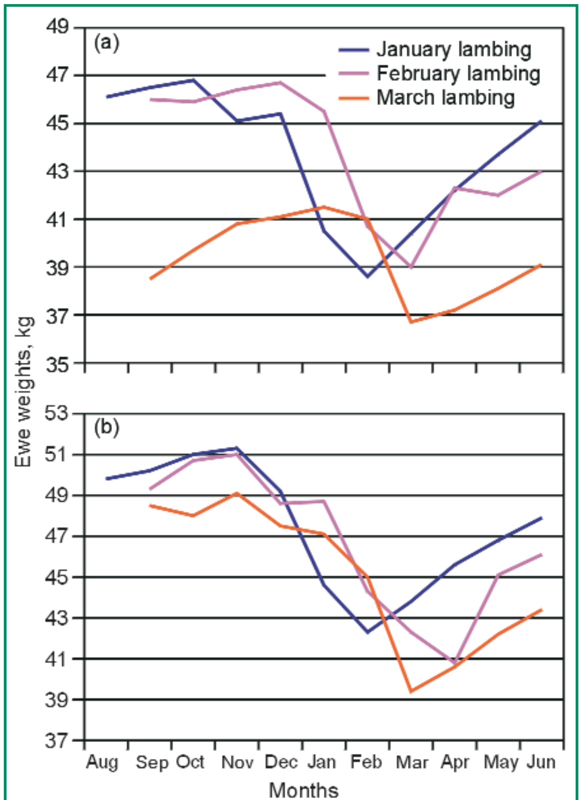


Fig. 19. Changes in live weight of Karakul ewes lambing in January, February, and March 2002: (a) Ewes that milked their lambs in 2001 and 2002; (b) Mary ewes that had their lambs removed after lambing in 2001 and that milked their lambs in 2002.

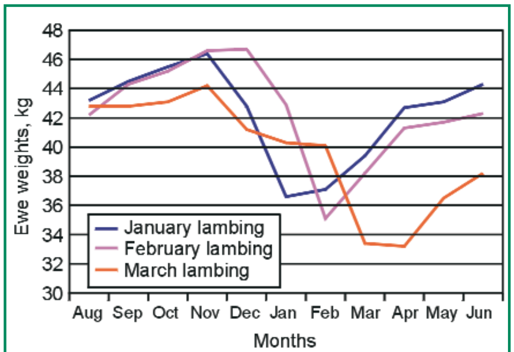


Fig. 18. Changes in live weight of Karakul ewes lambing in January ('winter'), February ('early spring'), and March ('spring/control'), 2001.

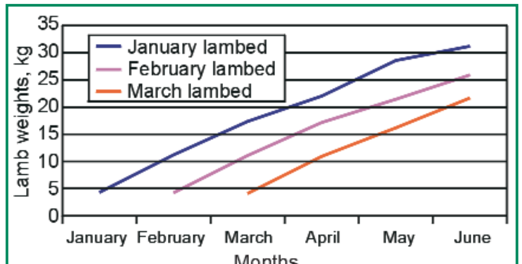


Fig. 20. Growth of lambs born in different lambing periods (average of two years: 2001 and 2002).

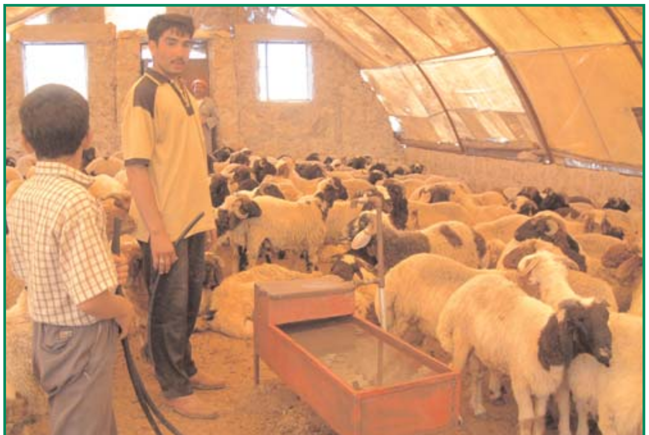
lambings. Farmers gained financially from being able to sell their ram-lambs early during the period of highest demand. However, the technology is associated with a 30-50% increase in feeding costs during winter. The implications of feeding costs are being evaluated against the productivity improvement observed to assess the feasibility of this technology.

Diversified lamb fattening systems for improved sheep production in Syria

West Asia's production environments are changing with the rise in population and rural-to-urban migration. This, coupled with market expansion, is opening up new opportunities while imposing new challenges and constraints. Demand for lamb, a traditionally popular meat, has increased in West Asia, and also in the affluent Gulf states, so much so that traders from the region are now importing lamb from West Asia into the Gulf. This has triggered an intensive trade in lamb and the widespread emergence of fattening systems that aim to capture the attractive prices in the market.

Several different types of fattening systems exist, each using different fattening methods and lambs of different ages. ICARDA's assessments have suggested that the fattening systems currently used in some areas of Syria could be extended to poor farmers for a steady income.

To identify how production could be improved through appropriate technological interventions, a better understanding of the systems used and their production constraints was needed. ICARDA conducted a comprehensive rapid appraisal of lamb fattening systems, mostly using Awassi sheep, in seven provinces in Syria. The study, involving 241 cases of fattening systems, identified opportunities for, and constraints to improved production and income generation. Five major types of Awassi-lamb fattening systems were identified (Table 17).



A sheep fattening unit in a village in Syria.

The average number of lambs per fattening batch was found to be 268 (with the range being 70 to 1000) while the average number of batches fattened per producer per year was 2.7 (Fig. 21). This figure fluctuated a little between provinces, demonstrating that the steady demand for lambs encourages a high turnover rate.

Depending on the province and the distance to a major market, fatteners engage in two different types of fattening: (i) as a sole business activity and/or (ii) as a method of selling excess lambs with a

Table 17. The five major Awassi-lamb fattening systems found in a survey in Syria in 2003.

Systems identified	Main features
Intensive fattening of 3- to 12-month-old lambs	• Situated around sheep markets in urban or peri-urban areas • High turnover of lambs • High number of lambs per batch • Intensive feeding, often in closed pens • Middlemen and moneylenders are often involved in these systems
Intensive fattening of cull ewes and rams older than 12 months	• Specialized fatteners engage in fattening of cull ewes and rams for consumption by the army and for periods of peak demand such as Ramadan and Eid El-Adha
Semi-intensive fattening of 3- to 12-month-old lambs	• Often situated in peri-urban areas or in the desert near main roads • Systems based on intensive feeding in paddocks and access to open areas (walking is the most common exercise); these systems incorporate very little grazing • Depending on the area, moneylenders from bigger cities are often involved in these systems
Semi-extensive fattening of 3- to 6-month-old lambs	• Opportunistic fattening of own lambs if prices are favorable • Typically systems engaged by Bedouins to sell excess lambs with added value • Lambs are reared with their mothers, fed concentrates, and grazed on the steppe until the age of 6 months • System is based on seasonal lambing, mostly occurring from December to March
Alternative fattening	• Intensive fattening of sick lambs and culled ewes bought cheaply at markets

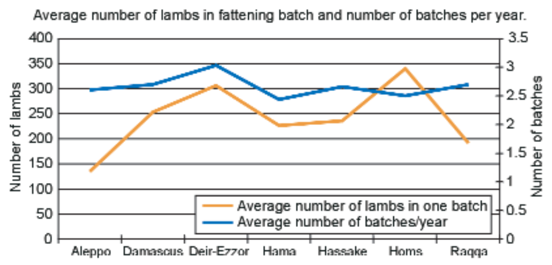


Fig. 21. Average number of lambs in one batch and average number of batches per year in lamb fattening systems in seven provinces in Syria (survey of 241 fattening systems).

higher added value. Some fatteners using the first production method buy all the lambs needed to make up a batch, while others buy additional lambs and add them to their own flock to build up a batch of a profitable size. Clearly, therefore, a variety of fattening strategies have been developed by farmers through their own ingenuity and initiative to utilize available resources and to suit their circumstances.

Current fattening systems rely heavily on concentrates, especially barley, wheat bran, legume straw, and cotton-seed meal (Fig. 22). These are usually high-cost inputs, with prices varying according to availability and climate (drought years or wet years). Practically no grazing was practiced by fatteners, because of the lack of grazing areas that could match the growth rates targeted by farmers, and an awareness that the animals waste energy if they have to walk far.

The main constraints to most fattening systems in Syria include (i) high feeding costs and (ii) health problems affecting lambs. Research is needed to find ways to reduce feeding costs, and develop low-cost, effective strategies that minimize health problems.

Fattened lambs are mainly sold as live animals to middlemen in the many urban and peri-urban markets around the country. They, in turn, resell the lambs to local markets or to bigger entrepreneurs who market to the Gulf areas. On the whole, fatteners prefer to target larger markets for two reasons: (i) live animals are weighed on scales and not estimated by eye and (ii) major buyers are present—these buyers export the lambs to Gulf states, where the highest returns are obtained.

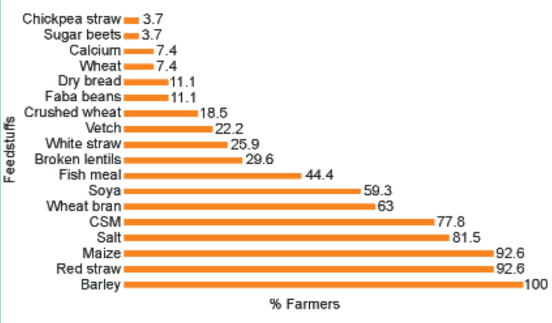


Fig. 22. Concentrates and feedstuffs used for fattening lambs in Syria. An example of 28 cases from Damascus.

Fattening farmers derive their livelihoods from a mix of opportunities for income generation. Although farmers stated that the income they receive from fattening was either 'high' or 'medium,' 56% had an alternative income (Fig. 23). Alternative income was mainly generated from agriculture-related activities, such as cropping, the transport of animals and feed, and the selling of feed.

Intensive fattening seems to be profitable and offers a relatively stable source of income throughout the year, with a demand that allows 2-3 batches of fattened lambs to be sold annually. It also accommodates other income-generating activities. However, starting and maintaining such operations requires capital that may not be directly available to resource-poor producers. The manner in which resource-poor producers initiate such production systems remains to be studied; however, it is apparent that fattening systems are inherently less risky than small-scale sheep husbandry which is unlikely to generate a sustainable income. Furthermore, there is a need to assess both the relationship between middlemen and fatteners, and the informal lending systems and other elements which govern lamb marketing both inside and outside the country.

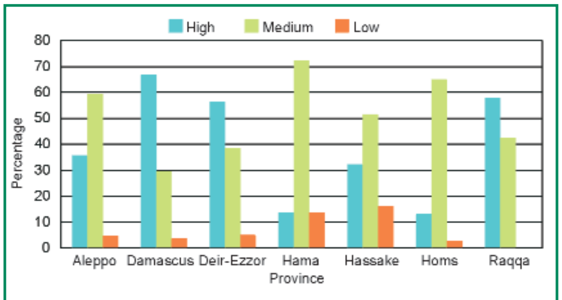


Fig. 23. Income ranking of fattening farmers in Syria.

Feeding costs and health problems were the key constraints faced by farmers. While a reduction in feeding costs would be easier to achieve if a large variety of feed resources is available, minimizing health problems could prove to be more difficult.

Project 3.1. Water Resource Conservation and Management for Agricultural Production in Dry Areas

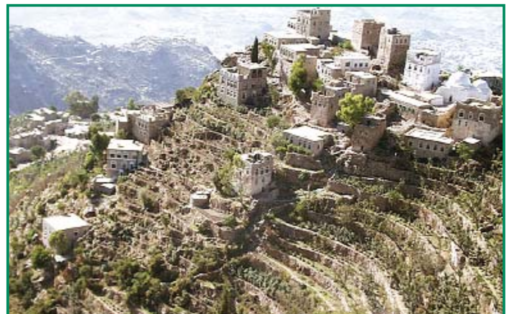
Efficient management of water resources is especially important in the dry areas of CWANA where water scarcity is severe. The use of traditional water-harvesting systems could substantially increase the agricultural outputs of the dry areas. In collaboration with a number of partners, ICARDA's research into the use, efficiency, and availability of such systems throughout CWANA has considerably improved the possibility of achieving that goal. Outputs in 2003 include a report which documents the current availability and status of traditional water-harvesting systems. It also assesses the indigenous knowledge which could be used to create improved versions of these systems by combining them with modern technology.

Documenting indigenous water harvesting systems in WANA

The dry areas of WANA are rich in traditional and ancient water-harvesting systems, indicating a wealth of indigenous knowledge that could be used to develop new practices and improve the efficiency of some of the systems still in use today. The systems can be very efficient as evident from the fact that farmers have practiced agriculture since ancient times in areas with an annual rainfall as low as 100 mm.

The growing scarcity of water calls for more efficient rainwater use. Even though water-harvesting techniques offer more environmental, social, and national benefits, many farmers and communities are failing to adopt water-harvesting techniques because:

- Land-tenure systems in many areas do not encourage the development of water-harvesting systems. Farmers are not willing to invest in land that they do not own, or do not have the right to use for a long period of time.
- Government policies are often not conducive to the development of such practices. Environmental protection measures are mainly passive, such as prohibiting the plowing of *badia* land in order to prevent desertification and land degradation.
- Water harvesting, though a low-external-input technology, requires inputs of resources for construction and maintenance.



Ancient contour bench terraces for water harvesting support coffee and *qat (Catha edulis)* trees in the mountains of Yemen even today.

Several years ago, ICARDA launched the regional initiative 'On-Farm Water Husbandry in WANA' which aimed to improve rainwater-use efficiency in the drier environments by integrating appropriate water-harvesting techniques and the conjunctive use of rainfall and other available water sources. Egypt, Iraq, Jordan, Libya, Morocco, Pakistan, Syria, Tunisia, and Yemen participated in the project. Key project activities addressed (i) water use in farming systems; (ii) the role of indigenous knowledge and end-users' perceptions and participation; (iii) water resources and the potential for water capture; and (iv) options to optimize water use.

The project concluded in 2003, producing a variety of outputs. One of the most important is a collection of reports on indigenous water-harvesting systems. The reports reveal the region's rich heritage in this field, and represent a major contribution to the documentation and analysis of this important source of knowledge. Inventories of potential water-harvesting sites in each country included the systematic collection and collation of data on soils, cropping patterns, water resources, and socioeconomic indicators. They showed that indigenous water-harvesting techniques are sustainable and environmentally friendly, with enormous potential for increasing the productivity of rainwater in the drier environments.

Moreover, the study demonstrated that the knowledge underlying such techniques is an integral part of the culture and history of local communities. Therefore, it is the most reliable starting point for the successful socioeconomic development of poor local communities in WANA's dry areas, especially when successfully blended with modern technologies. Plans for integrated land and water resource development should take into consideration all necessary technical, agricultural, socioeconomic and institutional aspects and inputs, and should include training farmers.

The project highlighted the fact that the benefits of water harvesting are not only economic—they are also social and environmental. Therefore, investment in these projects should not be the responsibility of farmers alone, but should be a national responsibility. Clearly, the support given to research on water-harvesting systems needs to be increased to ensure the large-scale adoption of improved techniques in the dry areas.

A volume on indigenous water harvesting systems has been published by ICARDA (www.icarda.org).

Project 3.2. Land Management and Soil Conservation to Sustain Rural Livelihoods

ICARDA's soil conservation and land management project focuses on areas where rural poverty is widespread, agricultural production constrained, and land is being degraded. It therefore targets two important ecosystems: (i) the dry margins of the agricultural area, and (ii) the hilly areas. Two benchmark sites in Northwest Syria have been selected as representative of these ecosystems: the Khanasser Valley (200 mm rainfall/year), where barley cultivation and sheep raising predominate; and Yakhour (500 mm rainfall/year), where the steep hillsides are mainly planted with olive. This research is being guided by the Integrated Natural Resources Management framework (see ICARDA Annual Report 2002), essentially a 'toolbox' containing process, diagnostic and problem-solving tools. Rural livelihoods are used as an entry point for the research, and land management and soil conservation are integrated into strategies to support and strengthen livelihoods.

ICARDA continued the innovative integrated natural resource management research projects in the Khanasser Valley and Yakhour, Syria, in 2003. Researchers developed user-friendly tools to quickly quantify losses due to soil-erosion, and used participatory nutrient mapping to target their research on preventing soil fertility decline. Studies found that low-external-input technologies could be extremely effective: water-harvesting structures provided olive trees with extra water, and 'priming' barley seeds with water and nutrients increased biomass production and water-use efficiency. Farmer-researcher cooperation also improved with the appointment of a new field facilitator, who is based in the Valley, and with participatory technology-evaluation activities within different farmer interest groups.

Tools to rapidly assess land degradation processes

In the dry areas, land degradation is very dynamic, due to variations in climatic and/or socioeconomic conditions. Unfortunately, limited labor and finances do not usually allow exhaustive assessments to be conducted. The development and testing of user-friendly tools that can rapidly assess the occurrence and causes of land-degradation processes is essential. The following assessment tools are being tested:

- **Water erosion:** Several models exist to predict water erosion rates (e.g. the Universal Soil Loss Equation or USLE). However, relying on such empirical tools is often risky since most of them apply only to particular agroecological conditions and require specific sets of preconditions which are often not met in the dry areas. Erosion surveys using the global positioning system (GPS) are a useful alternative. Besides mapping temporal and spatial variations, they can identify the causes of soil erosion. In the two benchmark sites, researchers found that water erosion was caused mainly by (i) overgrazing of the hillsides by sheep and goats, (ii) up-and-down tillage, and (iii) uncontrolled run-on of surface water from roads, tracks, and (animal) paths (Fig. 24).
- **Wind erosion:** To evaluate the impact of different cropping systems and soil surface states on dust generation, the project uses clusters of five samplers, each attached to a pivoting wind vane, to measure the amount of wind-blown dust at different heights above the ground in the Khanasser Valley (Fig. 25).
- **Tillage erosion:** Tillage erosion, the net downward movement of soil as a direct result of tillage operations, has been quantified using aluminum cubes (1.5 cm per side) as tracers. The cubes are easily detected using a metal detector and since their bulk density resembles that of soil particles, they move in a similar way, allowing researchers to measure the impact of different tillage operations on downward soil movement.
- **Soil fertility dynamics:** Soil fertility dynamics in dry agro-pastoral systems are quite complex. So, ICARDA researchers are working with farmers to build a semi-quantitative picture of nutrient flow via participatory nutrient mapping. Critical flows are then

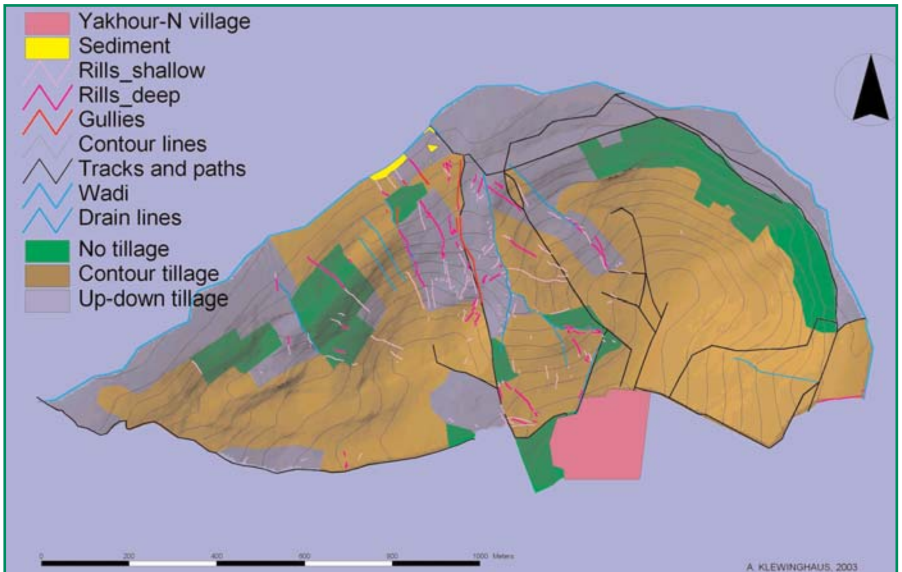


Fig. 24. A water erosion map at Yakhour (Northwest Syria) developed with simple GPS and GIS tools.

assessed through more quantitative monitoring and measuring in the field. This allows researchers to identify both nutrient leakages and methods which have the potential to improve nutrient-use efficiency. In Khanasser, the strategies farmers use to improve soil fertility are (in declining order of importance): fallowing, plowing, application of manure, application of mineral fertilizer, and rotation. The relationship between nutrient-management options and drought occurrence is a major concern for farmers.

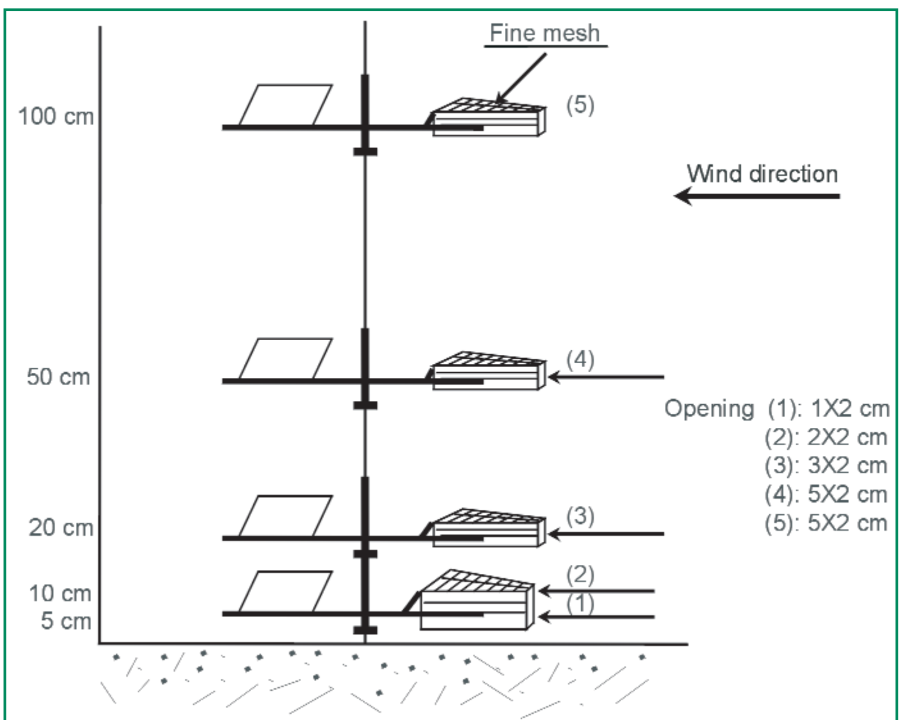


Fig. 25. BSNE (Big Spring Number Eight) sampler cluster for wind erosion dust measurement.

Land management techniques for dry areas

In Khanasser, two livelihood-support technologies have shown promising results: water harvesting in olive groves and nutrient-enhanced seed priming in barley cultivation. Olive, introduced into the Valley in order to diversify agro-pastoral livelihood strategies, has been rapidly adopted along the Valley's western slopes over the last few years. Currently, 23% of households in the village of Harbakiyah grow olive; but, this number could increase, as 74% of communities perceive olive growing to be an acceptable activity. However, although olive is drought resistant, annual precipitation in the Valley (200 mm/year) is below the optimum range for olive production (350-650 mm/year). So, water-harvesting structures are being used as a simple way to increase soil moisture availability without depleting groundwater resources. In this technique, V-shaped bunds collect water from a micro-catchment area and direct it to a tree planted at the lowest point within that area, simultaneously controlling the erosion caused by unchanneled run-off water. Such techniques have been known in WANA for thousands of years, but are presently underused.

In Khanasser, where the amount of rainfall necessary to generate run-off is relatively low (at least 7 mm/day), the structures increased the amount of water available to olive trees by an extra 200 l/tree during the 2002/03 winter. Slope gradient, micro-catchment area, and soil depth were all found to have a crucial influence on the efficiency of the water-harvesting structures. The need for supplemental irrigation during August and September was also

Water-harvesting structures, complemented with some supplemental irrigation in summer, make it possible to grow olives in areas considered too dry for olive cultivation (Khanasser Valley).

identified, as the additional water stored in the root zone during the rainy season was almost used up by early July.

The project is developing low-cost, fertilizer-use technologies, as poor farmers are unlikely to use large amounts of fertilizer in an inherently risky environment. One option being explored is the use of seed priming (short-term soaking of seeds in water followed by drying, causing moisture to be stored in the seed). Supplementing the soaking water with the nutrients that limit crop production in the target region could further increase the beneficial effects of priming. The optimum priming period for barley was found to be six hours. In a growth chamber, plants from nutrient-primed barley seeds showed better dry biomass production and water-use efficiency than either water-primed or unprimed seeds.

Improving farmer–researcher cooperation

Although process tools can improve the way researchers work with farmers and stakeholders, they often receive insufficient attention. ICARDA researchers are, therefore, testing a number of approaches to improve on-farm research.

Farmer participatory research has been used to improve the relevance of technology for users, reduce the research-to-adoption time lag, and increase farmers' knowledge and empowerment. Farmers and researchers collaborate via 'farmer interest groups' (FIGs): informal groups of farmers with similar production interests. Such groups diagnose production constraints and opportunities, select those options they feel need further research or extension support, and try new options on their farms.

Participatory technology evaluation allows interested farmers to observe and evaluate different technologies under on-farm conditions. The advantage of working with FIGs, as compared to working with communities, is that the cooperating farmers are more keen to participate. One constraint, however, is that possible conflicts of interest between a particular FIG and other land users may go unaddressed.

Trust and two-way researcher–farmer communication have also been improved by recruiting a full-time facilitator, based in the Khanasser Valley. The facilitator plays a crucial role, supporting on-farm research and providing scientists with feedback from farmers. In addition, an informal electronic bulletin, 'Voices of Khanasser,' has been initiated for collaborating scientists to provide regular updates on interesting issues raised by Khanasser farmers.

Participating farmers in the olive farmer-interest group select different technologies to feed into the research agenda.

Project 3.3 Agrobiodiversity Collection and Conservation for Sustainable Use

ICARDA continued its work in collecting, documenting, and conserving plant genetic resources in 2003, and the Center's germplasm collection grew by 2701 accessions. Studies using microsatellite markers showed that markers derived from expressed sequence tags were most effective for genotyping wild and cultivated barley. Also, GIS-generated information was used for ecological characterization of accessions in ICARDA's genebank, and to identify those tolerant to drought stress. In Jordan, Lebanon, Palestine, and Syria, a community-based agrobiodiversity conservation project continued to promote *in situ* conservation, seedling production, and successful income-generating activities based on the processing of local produce. ICARDA also conducted training and public-awareness campaigns, and developed new partnerships with NARS. Seed health of 19,000 incoming and outgoing samples and 170 hectares of on-station crops was tested. Nine seed health testing stations were set up in Afghanistan and a comprehensive in-country training course was offered in seed health testing and germplasm collection.

Germplasm collection and distribution

In 2003, ICARDA's germplasm collections grew by 2701 new additions and reached a total of 131,190 accessions. A unique set of 1335 accessions resulted from collection missions to Armenia, Jordan, Lebanon, Syria, and Tajikistan. The most valuable additions to ICARDA's collection were 529 unique accessions of bread and primitive wheats donated by the Vavilov Institute (VIR), St Petersburg, Russia, from germplasm collections made by Vavilov and his colleagues before 1941.

The Global Environmental Facility/United Nations Development Programme (GEF/UNDP) Dryland Agrobiodiversity Project funded a collection mission in Jordan, Syria, and Lebanon that was conducted by ICARDA and the national project components. The mission yielded a total of 80 accessions of wild relatives and landraces of cereals. Most importantly, 40 populations of *Triticum dicoccoides*, a wild progenitor of wheat endangered by genetic erosion, were identified and sampled. A population derived from the natural hybridization of durum and *T. dicoccoides* was also collected in southern Jordan.

In Lebanon, another germplasm collection mission focused on forage legumes. Planned and undertaken in June 2003 by ICARDA's Genetic Resources Unit (GRU) in collaboration with Lebanese NARS, the mission was supported by the Centre for Legumes in Mediterranean Agriculture, Australia, the University of Western Australia, and Ag–West Biotech, Canada. In total, 479 accessions of *Trifolium*, *Medicago*, *Vicia*, *Lathyrus* and various other minor legume species were collected from 39 sites.

In August 2003, a collection mission was conducted in Tajikistan, in collaboration with the Tajik Agricultural Academy and VIR. Researchers from CIMMYT and the Uzbek Botanic Institute also participated. The mission was funded by the Australian Center for International Agricultural Research, the United States Department of Agriculture, and the Grains Research and Development Corporation of Australia. The mission retraced parts of the route N.I. Vavilov followed last century when collecting in the high plateau region of the Pamirs (Fig. 26). The ICARDA-led team collected most of its material from within fields, field margins and harvested crops waiting to be threshed. The low

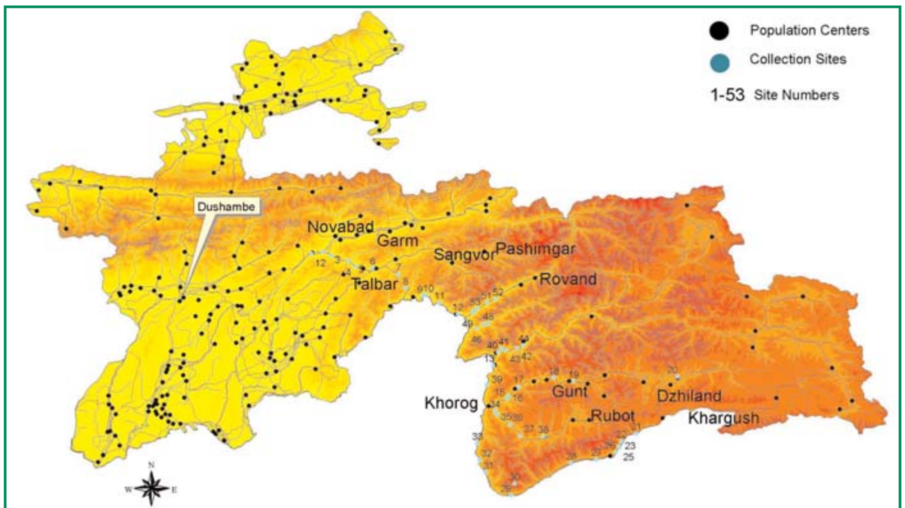


Fig. 26. Map of Tajikistan showing the collection sites (light-colored dots and numbers) of the Tajikistan plant collection mission, 11-28 August 2003. The colors on the map represent elevation: the darker the color the higher the altitude.

fertility of the region's rocky, calcareous alluvium soils, coupled with minimal husbandry and fertilizer input, are not conducive to the growth of modern cultivars. This makes the area a treasure trove of landrace forms specifically adapted to local conditions.

In 2003, ICARDA distributed nearly 20,000 seed samples on request. Of these, 6809 samples were sent to users in developing countries, 2402 to users in the developed world, and 10,697 to scientists in the ICARDA Germplasm Program.

Comparing microsatellite markers for genotyping wild and cultivated barley

To assess the most effective method for studying genetic variation in wild and cultivated barley populations, ICARDA researchers compared two different types of microsatellite markers—simple sequence repeats (SSRs) and expressed sequence tag EST-derived SSRs. An SSR is a microsatellite isolated from genomic DNA, which consists of a specific sequence of DNA bases and contains one to four nucleotides repeated in tandem. Expressed sequence tags (ESTs) are used to identify transcribed regions in a genomic sequence and to characterize patterns of gene expression in the tissue that was the source of the cDNA. A cDNA library and the International Triticeae Consortium (ITEC) database were used to source sequences for the EST-derived SSRs. Oligonucleotide primers were designed to match the sequences flanking these SSRs.

Researchers found that microsatellites derived from genomic libraries detected a higher level of polymorphism than those derived from ESTs. The polymorphism information content was higher in genomic-library-derived microsatellites than in their counterpart ESTs.

However, the EST-derived SSR markers developed in cultivated barley were found to be polymorphic in wild barley as well as cultivated landraces and improved varieties, and produced high-quality markers. Eight out of nine functional primers were polymorphic across the accessions studied. The EST markers showed the differences between wild and cultivated barley more clearly than the SSRs from genomic DNA (Fig. 27). The results showed that the populations that originated from the Fertile Crescent group were more diverse than those from other regions. As the EST-derived microsatellites are found within

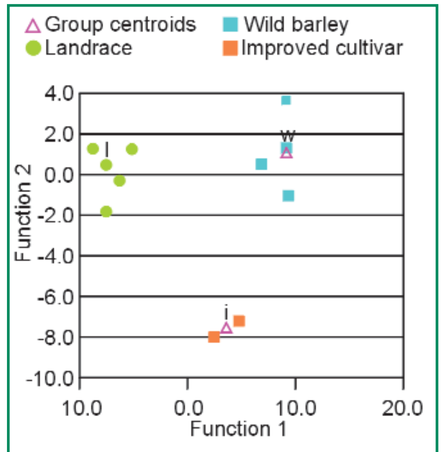


Fig. 27. Results of discriminant analysis, based on data from simple sequence repeats derived from expressed sequence tags, for different types of barley.

transcribed regions of the DNA, these markers should be more transferable than the anonymous SSRs.

In research on genetic resources, evaluation of the variation within germplasm collections is critical and could be enhanced by using molecular genotyping tools. The use of EST-derived SSRs could enhance the role of genetic markers by assaying variation in transcribed genes and those genes with known functions. The EST-derived SSRs obtained in this study provide a resource that can be exploited quickly in different studies of barley genetics.

Mixed cereal and legume field in Tajikistan.

Wheat spikes taken from the same field in Tajikistan.

Ecological characterization of cereal genetic resources

ICARDA started a new project in 2003 to explore the genetic potential of its germplasm collections. Funded by the German Federal Ministry for Economic Cooperation and Development (BMZ), researchers are working to identify sources of stress tolerance that will reduce the negative consequences of climate change.

Using GIS data generated by ICARDA's agroecological characterization group (Project 3.4), the project's researchers selected two sets of germplasm from ICARDA's collections: (i) a set of 36 wild barley and 124 barley landrace accessions, and (ii) a set of 36 *Aegilops*, 18 wild *Triticum* spp., 5 primitive wheat and 91 durum wheat landrace accessions. Forty-one ecological variables derived from two-step cluster analysis were used to select accessions representative of different clusters from drought-affected germplasm-collection sites. The two sets compiled will be complemented by other accessions of improved germplasm from ICARDA's Germplasm Program and used in molecular characterization studies in future phases of the project. Photothermal characterization will also be undertaken, as photoperiod and temperature affect the timing of important plant processes, such as flowering.

The newly generated GIS information was used to study ecological relationships among 25 wild species related to wheat, using univariate and multivariate statistical analyses. These analyses aimed to identify clusters of ecologically similar wild relatives that could act as donors of adaptive gene complexes when breeding wheat for tolerance to abiotic stress. The study was based on more than 12,000 accessions, from more than 3500 different collection sites with known geographical coordinates. These accessions are held in genebanks throughout the world, and are included in the Wild Wheat Global Database, which was developed by IPGRI and ICARDA, and which ICARDA maintains. The ecological relationships among 12 wheat wild relatives, identified using a multivariate analysis, are given in Fig. 28. One example is the cluster formed by *Aegilops longissima*, *Ae. searsii*, and *Ae. bicornis*, all of which are adapted to drought-affected environments. These results show that ecological adaptation relates to the phylogeny (evolutionary history) of species. Species that were old, in evolutionary terms, were found in the northern part of the Fertile Crescent, while newer species evolved in different environments in the east (*Ae. tauschii*), west (*Ae. caudata* cluster), and south (*Ae. longissima* cluster) of the area.

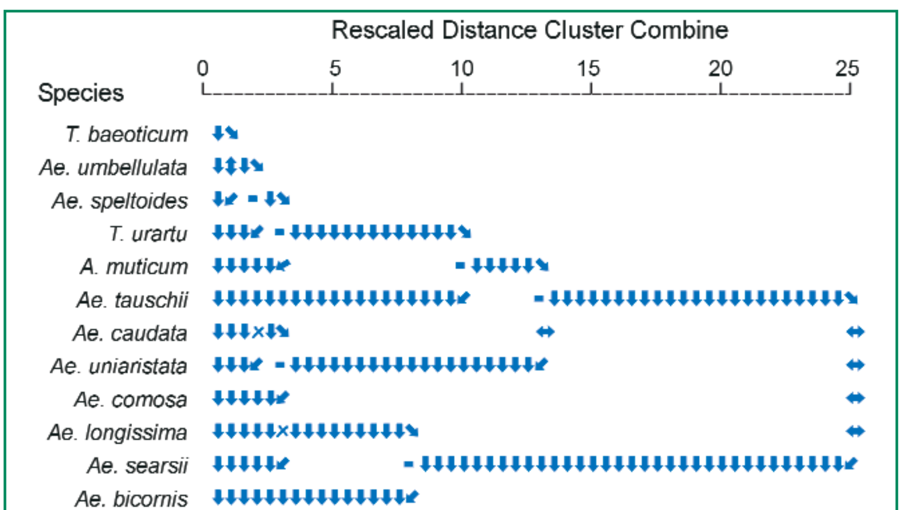


Fig. 28. Dendrogram indicating the ecological relationships among diploid wild relatives of wheat.

Richest spot in wild *Triticum* and *Aegilops* species in Ham site, Lebanon.

Community-based agrobiodiversity conservation in West Asia

In 2003, the GEF/UNDP-funded West Asia Dryland Agrobiodiversity Project continued its activities in Jordan, Lebanon, the Palestinian Authority, and Syria. The project aims to promote the conservation and sustainable use of landraces and wild species of global importance originating in the Fertile Crescent.

To meet the demand for indigenous tree species for afforestation, more than 210,000 seedlings and plantlets were produced by private, community, and government nurseries created by, or collaborating with, the project. More than 3.5 million seedlings of different species were multiplied by the Jordanian, Syrian, and Palestinian Forestry Departments. The Palestinian component of the project also distributed more than 32 tonnes of cereal and legume seed to collaborating farmers. Most of the harvest produced by these farmers was sold as seed to neighboring farmers.

The project also identified 15 sites rich in wild relatives of target crop species. These will become *in situ* biodiversity-conservation areas, through management plans drawn up in collaboration with local communities and government institutions. Two 'artificial' *in situ* conservation sites were created, by planting local species (that will be used for research), and three genebanks were established to conserve fruit-tree landraces. Collection missions, undertaken in collaboration with the participating NARS, sampled more than 40 populations of *Triticum dicoccoides* from Jordan, Lebanon, and Syria. Large populations of wild cereal and feed legume species have been conserved on more than 1500 ha in the Sweida region in Syria by banning grazing for some years.

Rangeland rehabilitation has been implemented over large areas in the following regions: Mahareb, Jordan; Aarsal and Nabha, Lebanon; Dahriya and Al Ganoub, West Bank; and Saana and Mushanaf, Syria. These options include reseeding with native legumes, applying phosphorus, and planting shrubs, in combination with water-harvesting techniques. Community involvement was emphasized during these activities.

On-farm and on-station trials were used to demonstrate to farmers that seed cleaning and treatment can increase the grain yields of cereal and legume landraces by 17-82%. Incentives are now being provided to encourage farmers and communities to buy seed cleaning and treatment equipment, in order to develop efficient, informal seed-multiplication initiatives. The positive impacts of different water-harvesting and IPM techniques on target fruit-tree species were demonstrated to collaborating farmers.

The project promoted the use of technologies for value-added products and alternative income-generating activities, through training, continuous technical backstopping, and the provision of incentives to members of local communities, principally women. Training and advice were provided to communities and individual farmers on the development of fruit-tree nurseries and the processing of wild and cultivated fruits to make dried fruit, jams, syrups, and compotes. Other income-generating activities included the cultivation of medicinal and herbal plants, the production of dairy products, honey, and mushrooms, and, in Lebanon, the initiation of eco-tourism activities.

Water harvesting techniques implemented for rangeland rehabilitation in Sweida, Syria.

In partnership with NGOs, the private sector, and the governments involved, the project is helping farmers to market their products. Local communities now have the opportunity to advertise their products, by participating in agricultural fairs. The project also created a permanent weekly market at Ajloun Castle, Jordan and organized agrobiodiversity fairs in Palestine and Lebanon, allowing individual farmers, local cooperatives, and NGOs to market local agrobiodiversity-derived products and handicrafts. Collaborating communities, NGOs, and male and female farmers are already benefiting financially from these initiatives.

The first Women's Traveling Workshop participants discuss the importance and usefulness of local products.

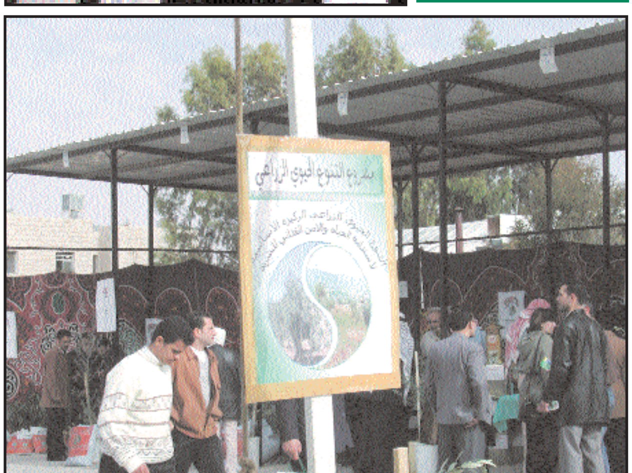
To build capacity and public awareness, the project organized seven regional courses and 38 national training courses and workshops in 2003, for more than 1430 participants, 400 of whom were women. Thirteen MSc students graduated and most of them are now working on the project. Traveling workshops for women and for herders allowed 35 participants to exchange knowledge and ideas by visiting various income-generating activities run by different projects at ICARDA headquarters in Syria, and project sites in Jordan and Lebanon.

Three thematic meetings on rangeland and livestock management; biodiversity and education; and community participation and sustainable-livelihood approaches were used to

Participants of the first Women's Traveling Workshop visited project sites in Jordan, Lebanon, and Syria.

assess the project's progress and to enhance regional integration and networking. Briefings on the project strategy, aims and activities were given to more than 5000 people through public-awareness events, including workshops, fairs, and conferences.

In partnership with the relevant Ministries of Education, efforts to include biodiversity issues within education systems continued in 2003. Biodiversity concept matrices, and methodological and scientific guides for teachers were drafted, and training provided to school teachers and education specialists. Gardens were created at schools and painting competitions and discussions within environmental clubs were organized. Students documented their parents' knowledge about local landraces and land uses. School theaters in Jordan and Palestine, and a rural theater in Syria, performed plays highlighting the need to conserve local agrobiodiversity and knowledge.



Left: Some of the public awareness materials distributed by the project.

Below: Agrobiodiversity fair in Muwaqqar, Jordan.

Public awareness was also enhanced through the use of mass media, and the production of posters, publications, T-shirts, postcards, and calendars. A regional documentary film was produced in English, French, and Arabic, and the Palestinian component of the project produced a documentary that has been shown several times on both national and private television channels. The project's work was highlighted in many broadcasts on Lebanese and Palestinian television.

To develop national agrobiodiversity policy and legislation, the Jordanian, Palestinian, and Syrian components drafted technical, socioeconomic, and institutional options that have either already been presented to Parliament (in the case of Syria), or are under discussion by multi-institutional committees. With the help of FAO, the collaborating countries are developing national policies and legislation governing access to plant genetic resources; these will be discussed by local communities before laws are drafted.

To ensure that the strategies and activities implemented so far are sustained, the Ministries of Agriculture in the four target countries and the directors of the national executing institutions formally requested that the efforts made by international, national, and local stakeholders continue. They declared that they would continue to support the project, and would apply the methods used to other ecosystems.

In 2003, the project provided biodiversity-enhancing in-kind incentives to lead farmers and local communities. The project helped local NGOs secure additional funds from GEF and other donors. The current collaboration with the Ministries of Education, the Environment, and Tourism will help ensure the continued use of agrobiodiversity in a sustainable manner.

The project's success in building a firm foundation for community-based biodiversity conservation was acknowledged during the fifth Regional Technical Planning and Steering Committee meeting held in Lebanon on 3-6 September 2003. Many NARS in WANA have approached ICARDA with a view to develop similar projects and benefit from the lessons learned by this project. ICARDA is now working to develop the required concept notes for projects involving NARS in Algeria, Morocco, and Tunisia.

Seed health testing

The use of healthy seed has two main advantages—it increases crop productivity and prevents the spread of pathogens. In 2003, ICARDA's Seed Health Laboratory (SHL) tested about 19,000 seed samples (8000 incoming and 11,000 outgoing). In all, 142 shipments were sent to 64 countries and 16 shipments were received from 10 countries. Most of the food and forage legumes and cereals imported were free of quarantine pathogens.

During the 2002/03 growing season, about 170 hectares at ICARDA's Tel Hadya station were inspected and plants infected with seed-borne diseases were rogued. Many common diseases were detected in different crops. In barley, spot blotch, barley stripe, scald, loose smut, and stripe virus were detected. Common bunt, loose smut, spot blotch, and flag smut were found in wheat, and ascochyta blight, chocolate spot, wilt/root rot, and *Orobanche* spp. in food legumes, and viruses in both cereal and legume crops.

Assisting Afghanistan: seed health testing and germplasm conservation

In 2003, ICARDA researchers undertook a variety of activities to rebuild Afghanistan's capabilities for seed health testing and genetic resource conservation. As part of the activities of the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), and with support from USAID, three comprehensive and six quarantine seed testing stations were installed. In addition, the Badam Bagh Seed Testing Station in Kabul was inaugurated as the country's national seed testing station.

As part of the FHCRAA action plan, ICARDA organized training courses on seed health testing for 11 participants from different regions of Afghanistan. The courses provided the staff of the newly established seed health testing units with the managerial and technical skills necessary to run the units efficiently. The use of the seed health testing equipment and facilities was demonstrated, to provide participants with an understanding of day-to-day activities.

A training course on germplasm collection and the use of global positioning systems (GPS) was given to 13 participants from the provinces of Kabul, Kunduz, Baghlan, Takhar, and Badakshan. The participants included representatives from the Aga Khan Development Network (AKDN), the Kunduz Rehabilitation Agency (KRA) and ICARDA staff stationed in Kabul and Baghlan provinces. The course covered the various aspects of germplasm collection missions, including: collection mission preparation; collection strategy; collection methodology; GPS use; sample registration - design and use of collection forms; and sample handling. The course included a collecting mission in an area 20 km west of Kabul.

In 2003, the national plant genetic resources conservation program was strengthened. Two agricultural research stations were visited near Kabul to identify a suitable site for Afghanistan's new Genetic Resources Unit. It was recommended that a fully functional genetic resources unit be established at Badam Bagh research station in the city of Kabul. The unit will be responsible for:

- Exploration and germplasm collection
- Documentation, characterization and conservation of genetic resources
- Seed health testing
- Environmental monitoring, using modern technologies such as remote sensing

A new building for the genetic resources unit, which would include storage facilities, has been planned.

Project 3.4. Agroecological Characterization for Agricultural Research, Crop Management, and Development Planning

Remote sensing and geographical information systems (GIS) are valuable tools for characterizing agroecosystems and identifying environmental trends over large areas. In 2003, ICARDA researchers developed three novel applications of these technologies. In order to successfully extend new crops or production practices to other areas, it is necessary to target similar areas. Researchers, therefore, developed 'similarity mapping' to identify areas across CWANA that were biophysically and socioeconomically similar to ICARDA's Khanasser research site in Syria. Scientists also developed a system for rapidly assessing biodiversity at the landscape scale, using remote sensing and easily observable land-cover/land-use characteristics. A new terrain map reflecting the relief intensity or ruggedness of the terrain was also created for agricultural researchers in CWANA.

Similarity mapping: identifying geographical areas with similar climates and socioeconomic conditions

A major bottleneck in the introduction of existing or new crops into different farming environments is the uncertainty about their productivity in those environments. This problem is particularly severe in the case of minor crops for which the ecological requirements are not usually well known. Multilocational trial data and simulation models are only available for the major commodity crops. One way to address this issue is to assume that a crop's performance will be identical in similar environments. By comparing all areas where crop performance is similar, it is possible to reconstruct the crop's ecological 'envelope' in terms of its requirements, tolerances, and sensitivities. The same principle can be extended to agricultural research in general: technological options for resource-poor farmers and communities developed in one dry area could be applied in other areas if the agroecological and socioeconomic conditions are similar.

To test this concept, a GIS study was undertaken to define the extrapolation domain for Khanasser, Syria, currently the most important benchmark site for ICARDA's research into integrated natural resource management. The approach used two different spatial frameworks to represent similarity in either biophysical or socioeconomic conditions.

To map biophysical similarity, only the climatic parameters such as temperature and precipitation have been considered so far. Climatic similarity was assessed by constructing a similarity index, based on simple distance functions, and comparing the monthly temperature and precipit-ation averages at the 'match' location, Khanasser, with those in the target region (CWANA and the northern Mediterranean). Similarity indices were first calculated for precipitation and temperature separately, and then in combination.

To map similarity in production systems, the regional Land-Use/Land-Cover map previously developed by ICARDA (ICARDA Annual Report 2000, pp. 49-52) was used. Only those land-use classes associated with Khanasser's main production systems (rainfed crop production and natural rangeland management) were retained. By combining the areas identified using the climatic similarity indices with the relevant land-use/land-cover classes on one map, areas with climates and socioeconomic conditions (patterns of land use/land cover) similar to Khanasser were identified (Fig. 29). Table 18 summarizes the areas with different levels of similarity. This confirms earlier findings that only a small part of the CWANA area is similar to Khanasser.

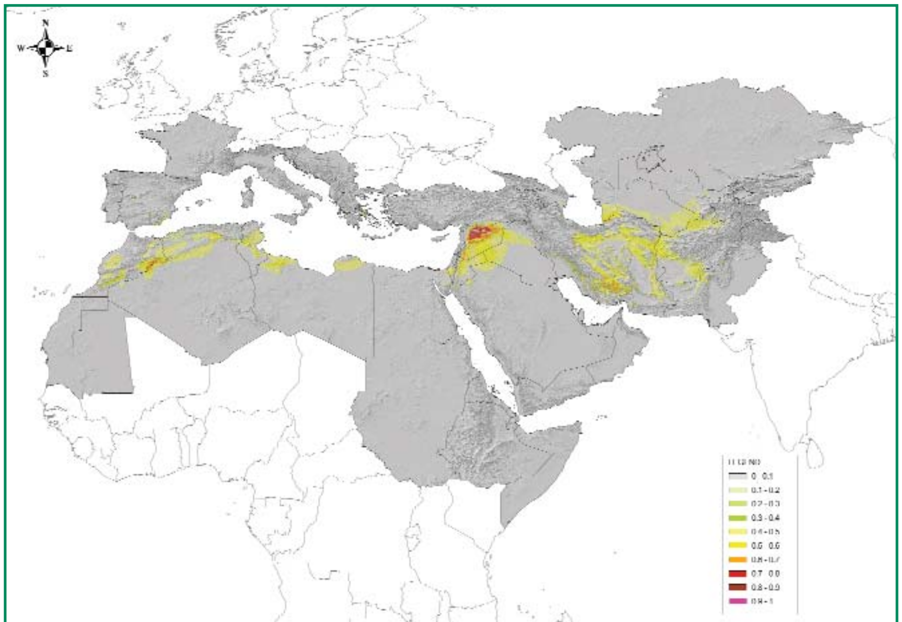


Fig. 29. Areas in CWANA with climates and land-use/land-cover patterns similar to Khanasser.

Table 18. Land areas with high similarity to Khanasser, Syria, derived from mapping of climatic and land-use/land-cover characteristics.

Similarity index[1]	Approximate land area in CWANA and the N. Mediterranean (sq. km)	Percentage of land area in CWANA and the N. Mediterranean
< 0.4	22,960,072	93.11
0.4 - 0.5	1,201,864	4.87
0.5 - 0.6	406,495	1.65
0.6 - 0.7	65,338	0.65
0.7 - 0.8	16,491	0.07
0.8 - 0.9	8,177	0.03
0.9 - 1.0	1,639	0.01

1 Higher values reflect greater similarity.

A simple system for rating landscape-level biodiversity

As part of the regional Conservation and Sustainable Use of Dryland Agrobiodiversity project, the Syrian General Commission for Scientific Agricultural Research (GCSAR) approached ICARDA to undertake a land-resource inventory study of two of Syria's designated agrobiodiversity conservation areas in Hafe and Sweida. Therefore, detailed land-cover/land-use mapping was undertaken in both areas using Landsat imagery, the CORINE Level 3 classification system, developed by the European Environmental Agency, and fieldwork for ground-truthing.

Land-cover/land-use maps were created in vector format using the GIS ArcView software. These are linked to a spatial database that contains, for every mapping unit, information on land cover/use with a maximum combination of three kinds of land cover/use for every mapping unit, their coverage (percentage), the occurrence of small landscape elements (e.g. hedges, terraces, *wadi*s, and large trees), and a biodiversity rating, which depends on the amount and type of natural vegetation present.

Biodiversity rating was used to evaluate the importance of diversity within the mapping units (Table 19). The Biodiversity Rating Map for the Sweida area is shown in Fig. 30. This rating system uses physiognomic classes, based on easily observable features, and can be adapted to different land-use/land-cover classification systems. Therefore, it is particularly suitable for rapid visual assessment and mapping at the landscape level. It is not intended to replace detailed botanical surveys at sampling sites. However, because of its focus on meso-scale variability, it can be used to target these surveys more precisely and ensure that sampling is representative. The rating system is linked to a detailed land-use/land-cover classification, and so the rating is objective and reproducible. At the same time, the fact that the rating scale relies on visual observations provides a reality check and makes optimal use of expensive and time-consuming field work. The rating scale can also be developed in a participatory manner to ensure that local values are incorporated. The combination of visual observations and remote sensing used in this project makes accurate mapping possible, and will be used in ICARDA's work in the future.

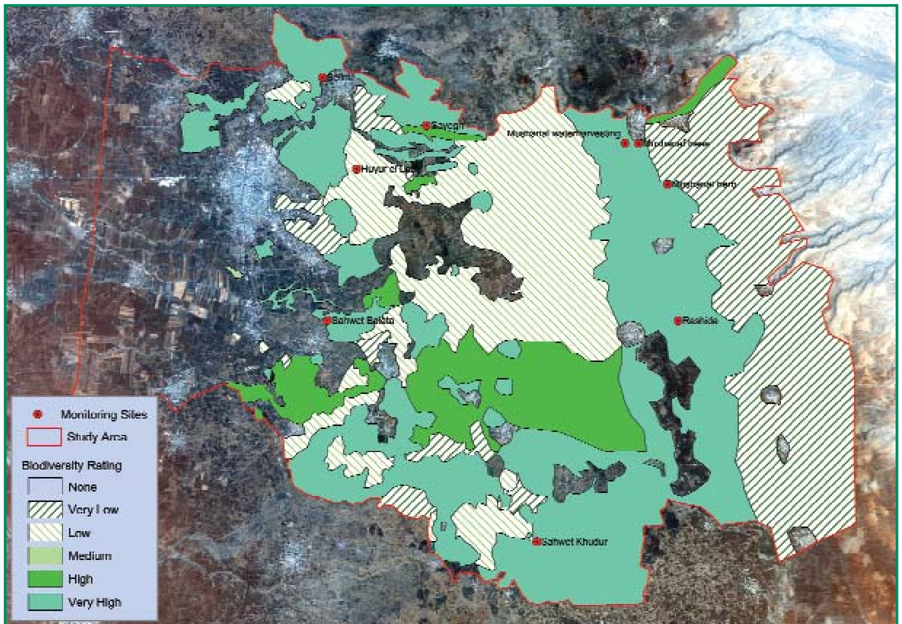


Fig. 30. Landscape-level biodiversity rating of Sweida, a designated agrobiodiversity conservation area in Syria, obtained using a simple system involving remote sensing and visual observation.

Table 19. Relationship between land-cover/land-use types (CORINE Level 3) and biodiversity ratings.

Land cover/use (CORINE Level 3)	Biodiversity rating[1]	Land cover/use (CORINE Level 3)	Biodiversity rating[1]
Continuous urban fabric	1	Agroforestry areas	4
Discontinuous urban fabric	1	Broad-leaved forest	6
Industrial or commercial units	1	Coniferous forest	4
Road and rail networks and associated land	1	Mixed forest	6
		Natural grasslands	6
Airports	1		
Mineral extraction sites	1	Maquis (tall shrubs)	6
Construction sites	1	Garrigue (short shrubs)	6
Green urban areas	2	Transitional woodland scrub	5
Sport and leisure facilities	1	Bare rock	2
Non-irrigated arable land	1	Sparsely vegetated areas	2
Permanently irrigated land	1	Burnt areas	1
Vineyards	1	Inland marshes	6
Fruit trees and berry plantations	1	Salt marshes	6
		Saline depressions	3
Olive groves	1	Water courses	1
Pastures	1		
Annual crops associated with permanent crops	2	Water bodies	1
Complex cultivation pattern	1	Mixtures of fruit trees & vines in equal quantities	1
Land principally occupied by agriculture with significant areas of natural vegetation	4	Mixtures of fruit trees & olive trees in equal quantities	1

[1] Biodiversity rating: 1 = none, 2 = very low, 3 = low, 4 = medium, 5 = high, 6 = very high biological diversity.

New ways of mapping landforms in CWANA

For the different agroecological zones in CWANA to be defined, reliable information on the

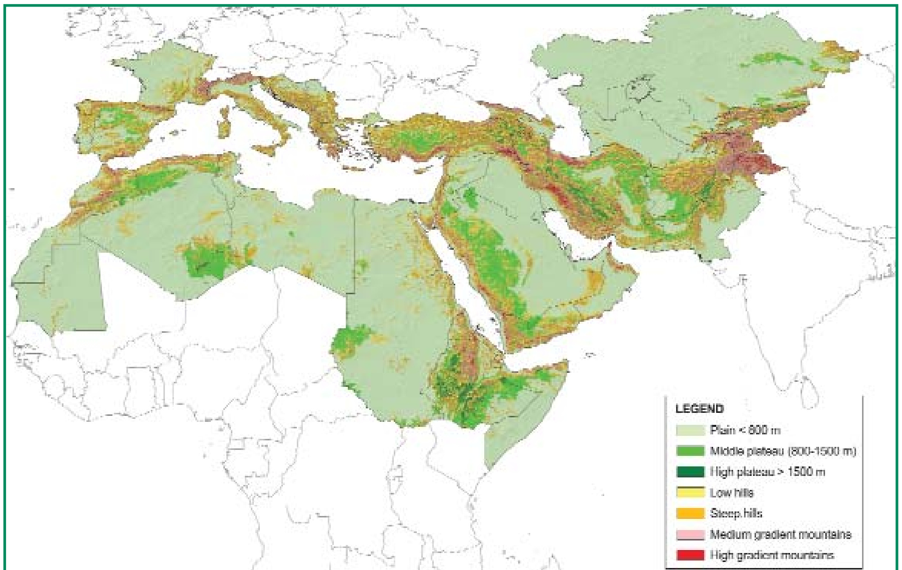


Fig. 31. The new CWANA Terrain Map, reflecting the relief intensity (ruggedness) of the terrain as well as elevation.

region's landforms is needed. Nowadays, a digital elevation model (DEM) is a prerequisite for all GIS-based terrain assessments. A DEM is simply a data string listing elevation against geographical position. Yet, elevation does not really show a landform. To identify landforms, a minimum of two criteria are needed: absolute elevation and the degree of dissection, or 'ruggedness.' The latter can be expressed by the difference in elevation between adjacent high and low points.

A global DEM (GTOPO30), created by the U.S. Geological Survey, was available for use in defining CWANA's landforms. However, because GTOPO30 has a resolution (pixel size) of 1 km, it gives no real indication of 'slope.' Therefore, the parameter 'range' indicating 'relief intensity' was calculated because it is a more reliable indicator of landforms.

The range or relief intensity can be defined as the median difference between the highest and lowest point within the terrain in a specified distance, and is expressed in m/km. However, when working in a huge study area such as CWANA, and when coarse-resolution data are used in a geographical coordinate system to calculate the relief intensity, significant underestimates of the true relief intensity are bound to occur, given the curvature of the earth. Therefore, ICARDA's researchers developed a new method for calculating accurate relief intensities.

The first step in this process was to consider the latitude and longitude of all the pixels and make projection adjustments. Researchers developed an algorithm to obtain a latitude-adjusted relief intensity. The second step consisted of classifying the adjusted relief-intensity values into five terrain classes ('plains,' 'low hills,' 'steep hills,' 'medium-gradient mountains,' and 'high-gradient mountains'), to construct a relief intensity map. To create the final terrain map, the relief-intensity values were combined with altitude information from GTOPO30, which allowed three sub-classes to be created within the terrain class 'plain.' This resulted in seven classes, based on absolute elevation and relief intensity (Table 20), that are used in the final terrain map (Fig. 31).

The number of classes can be increased by considering more elevation or relief-intensity intervals. However, a high number of classes would be undesirable when developing a map of agroecological zones, as such a map is, by nature, based on the integration of multiple themes. The new terrain map is already being used to characterize the different highland environments found in CWANA, thereby helping researchers identify germplasm suitable for use in specific environments.

Table 20. Final terrain classes used in the construction of a new terrain map for CWANA.

Terrain class	Relief intensity (m/km)
Low-altitude plains (altitude < 800 m)	0 - 50
Medium-altitude plains (altitude 800 - 1500 m)	0 - 50
High-elevation plateaus (altitude > 1500 m)	0 - 50
Low hills	50 - 100
Steep hills	100 - 300
Medium-gradient mountains	300 - 600
High-gradient mountains	> 600

Project 4.1. Socioeconomics of Natural Resource Management in Dry Areas

In order to maintain and improve the livelihoods and welfare of CWANA's rural poor, the fragile resource base that supports the region's agriculture must be preserved. In 2003, ICARDA analyzed the national policies, land-use changes, and well-drilling activities to determine the causes of the overexploitation of Syria's groundwater. Researchers also assessed the profitability of groundwater use in different production systems and modeled groundwater demand in response to changes in crop prices and irrigation costs. In Yemen, researchers identified the social and socioeconomic changes underlying land degradation. They also highlighted policy gaps, and recommended ways to improve access to rural credit, help communities strengthen their natural resource management efforts and save their famous mountain terraces. In the Khanasser Valley in Syria, detailed studies were carried out to determine how recent changes in natural resource management policy are affecting farmers and rural livelihoods, and identify policy gaps.

Forces driving groundwater exploitation

Due to the growing populations and development activities, most CWANA countries face increasing water scarcity. Agriculture is the largest user of fresh water and water is the most important limiting factor affecting agricultural production in the dry areas. So, research into the economic, institutional and policy issues that affect agricultural water management is essential to develop interventions that will ensure more efficient, sustainable, and equitable use of scarce water resources.

ICARDA researchers measure the groundwater discharge along with a participating farmer in Barshaya village in Syria to collect data for their survey.

In 2003, ICARDA analyzed data from a groundwater study conducted in five villages, covering four agricultural stability zones in Syria. The study compared the relative profitability of the different systems that use groundwater drawn from shallow aquifers. It also identified the main forces driving groundwater exploitation. Researchers analyzed groundwater demand and irrigation costs, modeled farmers' groundwater investments, and determined the probability of successful drilling. A dynamic simulation model encompassing different systems was then developed.

The study revealed that water-management practices implemented over the last few decades have had negative effects. Groundwater use has transformed sustainable traditional livestock–barley farming into unsustainable groundwater-irrigated systems, leading to out-migration once the groundwater was depleted. The high sale price of wheat and cotton guaranteed by the government, coupled with the low cost of pumping fuel and open access to groundwater, has caused more areas to be allocated to crops with a high water consumption, such as cotton, accelerating groundwater exploitation and depleting aquifers. The study also found that the demand for water associated with crops that consume a lot of water varied in response to price and cost changes. Hence crop prices and the cost of irrigation play an important role in the sustainability of water use.

Researchers found that farmers tended to take risks to maximize their profits. Although they knew that investing in groundwater irrigation was risky, farmers felt that this was offset by the high pay-offs obtained over a short period of time if drilling wells was successful. This led to accelerated well-drilling. However, as the number of wells increased, the probability of success dropped, and many farmers who continued to invest found that they could not recover their investment. If fuel prices were increased by 50%, then growing crops that consume a lot of water —such as cotton— would not be profitable, particularly in areas where pumping costs are relatively high because aquifers have been depleted. This potential policy option could, therefore, prevent the area planted with such crops from expanding further. Crops such as vegetables, grown in combination with wheat, therefore constitute a more sustainable option than cotton.

Recently, there have been important policy changes concerning water in Syria, including programs requiring farmers to use water-saving technologies, and reduce excessive water use in agriculture. When fully implemented, these policies will improve agricultural water management.

Analyzing policies affecting land use and terrace maintenance in Yemen's mountains

Table 21. Factors influencing terrace maintenance in Yemen's mountains before and after the 1960s.

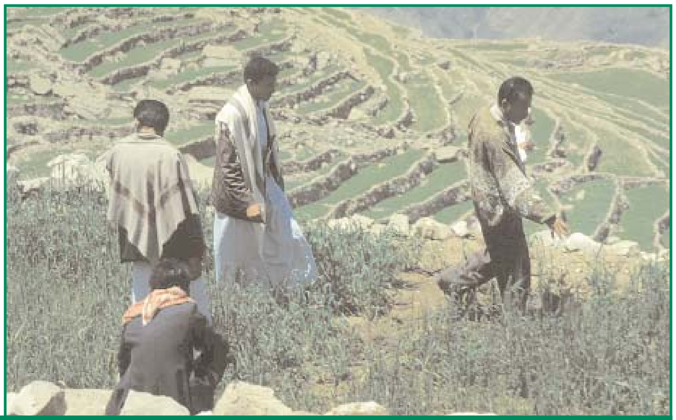
Factors contributing to sustainable land use	Factors contributing to land degradation during and after the 1960s
- Labor was abundantly available and relatively cheap - Land was the main source of food and livelihoods - There was a strong sense of community cohesion, which was necessary for survival in remote villages - Communities were relatively isolated from the rest of the world, which fostered self-sufficiency in food - Customary rules were strongly applied and collective action taken	- Male out-migration created labor shortages - The opportunity cost of labor increased, as other sources of income could be accessed - Trade and subsidized food prices caused the communities' reliance on subsistence farming to decline - Economic returns gained from production decreased - Mobility and communication improved, causing 'labor migration' and reducing the cost of imported food - Socioeconomic changes weakened community cohesion - Modern laws and social change undermined local rules and collective action

In Yemen, the welfare of the people and good land management were inseparable for many centuries, as most agricultural land consisted of mountain terraces that farmers built themselves. But, recent dramatic socioeconomic changes have affected the Yemeni people's livelihoods and the ways they care for their land.

ICARDA conducted a study to analyze the policy and institutional factors affecting terrace maintenance in Yemen, in collaboration with the Agricultural Research and Extension Authority (AREA) of the Ministry of Agriculture. Farmers and officials working in government and other institutions such as banks and development programs were interviewed to (i) assess how socioeconomic changes over the last four decades have influenced terrace maintenance, and (ii) determine how aware rural mountain communities are of the resources available to maintain their terraces and build their livelihood assets.

Analyses of the interviews showed that, although conditions prior to the 1960s promoted investment in terraces and land conservation, the socioeconomic climate following that decade has favored less investment in land improvement, leading to terraces being abandoned and degraded (Table 21).

Important policy gaps that affect both the adoption of sustainable terrace farming and the livelihoods of rural communities in Yemen's mountains were identified. Agricultural support, mainly through a diesel subsidy, has largely benefited irrigated agriculture and large-scale farmers. Farmers in the mountain terraces, who mainly depend on rainfed crops and seasonal springs, have received no tangible benefits from such schemes. Similarly, support that targeted the development of large spate-irrigation systems benefited spate systems in the flat downstream areas, but had no impact on mountain terraces. Also, subsidized wheat imports, which mainly benefit urban consumers, have reduced the profitability of rainfed farming on mountain terraces where

The mountain terraces in Hajja Province, Yemen, can be found as high as 3500 m above sea level, and have been used for centuries (*Left*: Degraded terraces; *Right*: Productive terraces).

cereal crops dominate. This has reduced the returns obtained from investment in terrace reconstruction and rehabilitation. Therefore, though the policy may have helped poor rural households access cheaper staple foods like wheat, the negative effects on food production and employment outweigh any positive effect on food security for rural mountain households.

Access to capital for agricultural improvement was also identified as an area of concern. Three main institutions provide financial capital to rural communities in Yemen: the Cooperative and Agricultural Credit Bank (CACB), the Agricultural and Fisheries Production Fund (AFPPF), and the Social Fund for Development (SFD). The different programs and credit facilities provided by these institutions seemed ideal for addressing the issues faced by small-scale farmers in Yemen's mountains, such as poverty, technology access and land improvement, including terrace rehabilitation. But, the study found that small-scale farmers' access to the opportunities offered by these institutions is negligible.

This is because, first, there has been a systematic bias in favor of large farms and irrigation rather than soil and water conservation in the upper catchment areas, such as the mountain terraces. Second, CACB loans during the period 1990-2000 were neither pro-poor nor pro-rainfed agriculture. The relatively few borrowers were not the poorest farmers, who depend on rainfed agriculture and live in the mountains. Third, the number of projects funded by the AFPPF was small in relation to need, while the locations of those that were funded did not reflect the poverty concentrations of the different governorates. Fourth, local Directorates of the Ministry of Agriculture seem to believe that the SFD lacks either the will or the capacity needed to implement programs that benefit rural mountain farmers. Finally, rural communities in the study are unaware of these programs. The following policy, institutional, and technological interventions were identified to strengthen natural resource management and sustainable livelihoods in Yemen's mountains and close the policy–development gap.

- Community-based organizations, such as enterprise production and marketing groups, saving and credit associations, and water users' associations, should be organized. These will enhance community coordination when acquiring credit and increase community bargaining power, market access, and access to other services from development institutions. Such local organizations could collectively maintain and rebuild terraces, as well as perform other land-improvement activities.
- Saving and credit associations, capable of accessing funds from formal financial institutions, should be created at the village level, as grass-roots micro-finance intermediaries. The inability of rural credit institutions to reach the rural poor, in particular those living in the mountains, calls for these institutions to be restructured, with community capacity building as an explicit goal.
- Water shortages, identified by the communities studied as the single most important problem they face, need to be addressed. Water harvesting and storage structures already exist, but their efficiency needs to be improved. Farmers have good ideas about how to improve them and have developed proposals based on these ideas. Rural credit could be used to support investment in these and in terrace maintenance.
- Before effective technology development and transfer can take place in the terraced mountain areas, researchers need to understand their complex multiple agricultural systems, which use different types of crops and animals, each suited to different conditions. The uses and niches of these species need to be recognized, in relation to seasonal variations and the altitudinal gradients present even in relatively small micro-watersheds. The limited number of functional climate stations in Yemen hampers the characterization of these complex environments. In particular, farmers would benefit from greater access to fertilizers and improved sorghum, wheat, barley and legume seed, as well as from improved agronomic practices to increase the yield of high-value crops, such as potatoes and coffee.
- The marketing of cash crops, particularly potato and coffee, should be supported using information generated by marketing studies. More and stronger links are also required between institutions and farmers.

Policies and institutional factors affecting land use and rural livelihoods in the Khanasser Valley Integrated Research Site, Syria

Many countries in the CWANA region lack appropriate policies for the sustainable use of natural resources. Where they exist, natural resource management policies play a major role in determining long-term management practices and the adoption of new resource-saving options. However, in the short term, they often have a negative impact on poor resource users, and may contribute to the degradation–poverty downward spiral.

Recent policy changes in Syria, for example, aim to encourage more efficient, equitable, and sustainable resource use. To determine farmers' responses to the new policies, as well as how these responses affected land use and their own livelihoods, ICARDA conducted a study in Khanasser Valley, a dry marginal area in northwest Syria (Fig. 32). Village-level surveys, household surveys, participatory community surveys, expert opinions, and a review of the literature concerning the macro-level changes that have influenced the region identified several policies that have affected land use and rural livelihoods. These include:

- the regulation of sheep exports, which has increased the risk of financial losses in lamb-fattening enterprises, which are a major economic activity in the area.
- the banning of barley cultivation in the rangelands, with the aim of restoring natural pastures; this has reduced the supply of feed and thus the profitability of sheep production.
- the banning of cotton cultivation and digging wells, to avoid excessive groundwater abstraction.

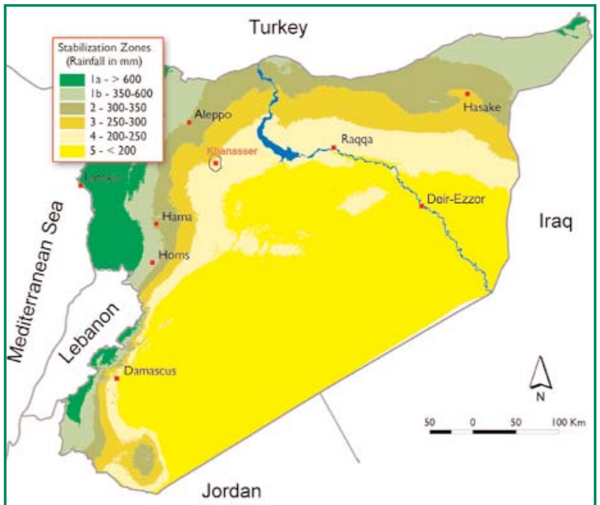
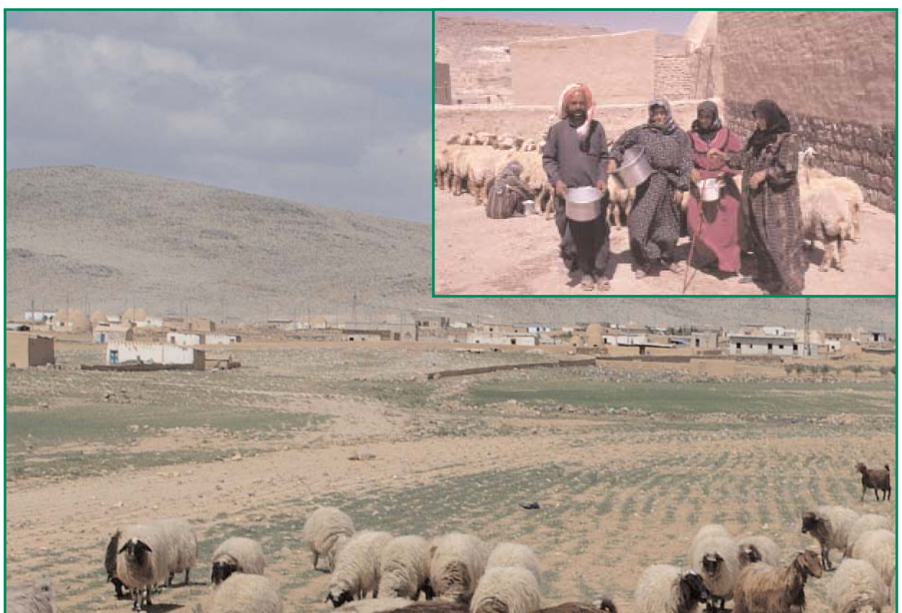


Fig. 32. Location of ICARDA's Khanasser Integrated Research Site in Syria.

Though the latter two policies will have a positive impact on natural resources, particularly on natural pastures and groundwater levels, some of the farmers surveyed said that these policies have, already had a significant negative effect on rural livelihoods. Farmers have formulated their own coping strategies, including seasonal migration and, in the case of the poorest, who used to cultivate the steppe but now have no cropland to maintain at home, permanent out-migration to neighboring countries, mainly to find agricultural work. Other coping strategies involve off-farm employment such as olive picking and construction work in nearby towns.



Typical landscape and people of Khanasser.

The study identified several development policy gaps that are currently causing hardship for rural communities. These include (i) a lack of credit facilities, which, if available, could help resource-poor farmers build their assets and improve their livelihoods, by allowing them to develop such economic activities as lamb-fattening, and (ii) weak extension services and a lack of technical support for technology diffusion and resource-management options, as well as a lack of information on markets.

Addressing these policy gaps would minimize the negative effects of natural resource management policy initiatives. Analysis of the full effects of these policy changes will enable policymakers to make informed decisions when formulating further policy initiatives. Therefore, ICARDA is now conducting detailed studies to quantify the effects of current policies on rural livelihoods in Syria.

Project 4.2: Socioeconomics of Agricultural Production Systems in Dry Areas

Knowledge gained through socioeconomic studies can be applied when researchers work with farmers to develop improved, more sustainable production systems and household livelihood strategies. In 2003, ICARDA conducted a detailed study of poverty levels in the Khanasser Valley. Current livelihood strategies were identified, as were a variety of potential improvements. Work to improve rural livelihoods and save Yemen's mountain terraces also continued, with a participatory study of household poverty levels and the role of women in the community. Key issues for action were identified and a variety of measures proposed to aid the rural poor. ICARDA also completed a detailed study of the nutritional status of rural children from different livelihood groups in northwest Syria. The information gained will allow researchers to target the needs of poor households in marginal areas more effectively.

Rural livelihoods analysis in Khanasser, Syria: improving the livelihoods of the poor

ICARDA conducted a rural livelihood study at its integrated research site in the Khanasser Valley, Syria, where agroeconomic conditions are representative of many marginal environments in the CWANA region. Research partners include Syria's Olive Bureau and Atomic Energy Commission, the Jebel al Hoss Development Project, extension services, and the University of Bonn, Germany. Researchers have documented people's perceptions of local poverty levels and current rural livelihood strategies, and have explored ways of improving livelihoods. Data was collected in 31 villages using rapid rural appraisals, semi-structured surveys, and interviews with key informants in each village. The local people's perceived well-being and poverty indicators were then grouped under the headings 'natural,' 'human,' 'financial,' and 'physical' capital (Table 22). Using these indicators, about 13% of households were classified by local people as 'very poor,' 48% as 'poor,' 33% as 'moderately well-off,' and 6% as 'well-off.'

The villages were then characterized using cluster analysis and GIS, based on key variables such as population density, production orientation, land use, property rights, available services and infrastructure, and livelihood strategies. Three clusters of villages with broadly similar livelihood strategies were thus identified (Table 23): Group I, agricultural production; Group II, off-farm work and sheep fattening (an important economic activity for 15% of households); and Group III, off-farm labor and migration. A key finding was that off-farm employment was an important livelihood strategy: around 53% of households had members who worked as off-farm wage laborers, 20% had members who worked as laborers in cities, and 13% had members who worked outside Syria. The wide spatial variation of perceived poverty levels is shown in Fig. 33.

Representative villages were selected from each of the three

Table 22. Indicators of well-being and level of poverty in Khanasser, as perceived by local people.

Capital	Very poor	Poor	Moderately well-off	Well-off
Natural	No sheep	Few sheep (1-5 head)	Medium sheep flock (20-50 head)	Large sheep flock
	Landless or small land area (1-3 ha)	Small land area (2-5 ha)	Medium land (15-25 ha)	Large land area
				Own well and have irrigation
Human	No off-farm work Sick Unable to work	Only one laborer	More laborers Members working outside Syria	Off-farm income Government employment
Financial	In debt	No cash	No debt Enough cash to run business Fattening of own sheep Work in straw trade	No debt Have fattening sheep work Sell drinking water
Physical				Own lorry and/or tractor
Households (%)	13	48	33	6

Table 23. Clusters of villages with similar livelihoods in Khanasser.

Cluster of villages	No. of villages	Main characteristics	Dominant livelihood strategies
Group I	4	Relatively large land areas; large rangelands for grazing; good asphalt road; few households with members working as off-farm laborers	Agricultural production
Group II	15	Small land area; small rangeland areas; fewer public services (electricity, school, etc.)	Off-farm work; Sheep fattening
Group III	12	High population density; smaller land area; better infrastructure	Off-farm work, migration

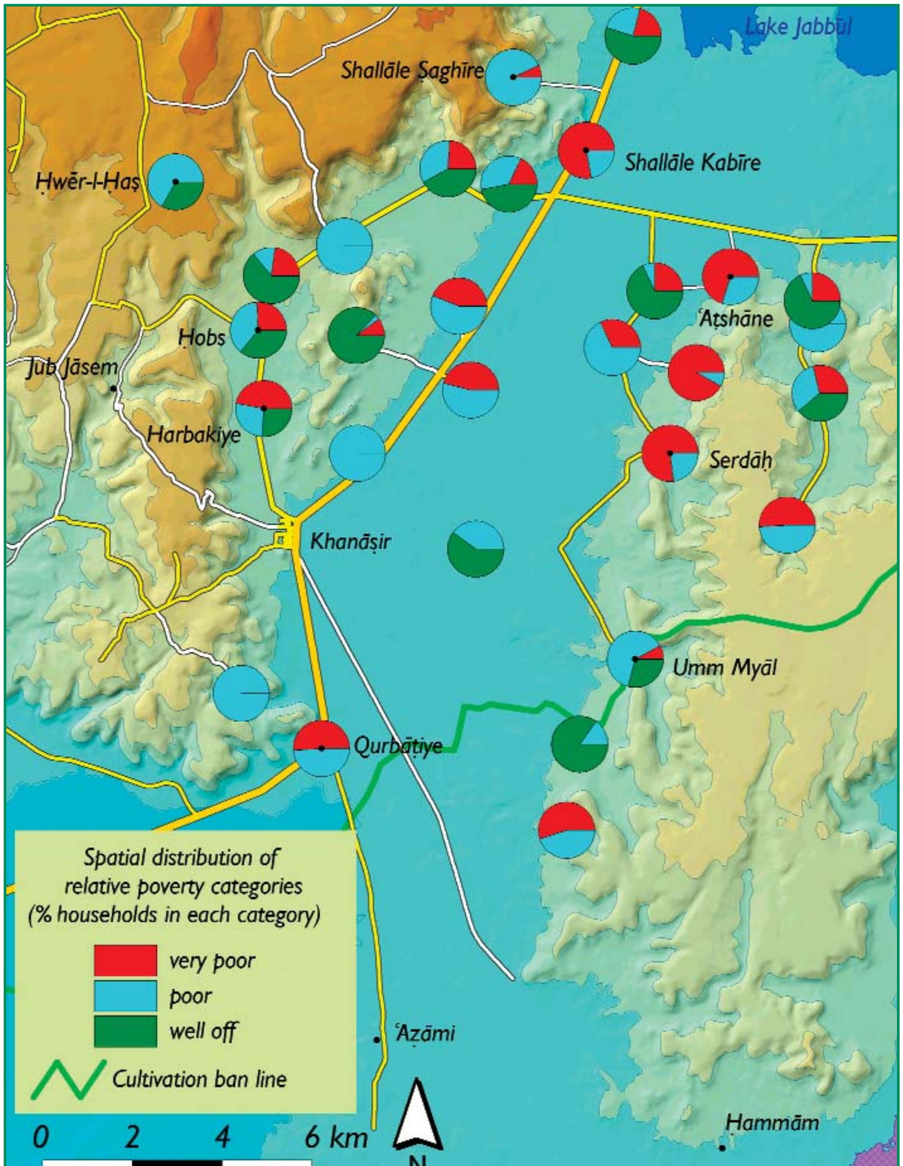


Fig. 33. Poverty map of Khanasser, Syria, constructed using GIS and cluster analysis with data from rapid rural appraisals undertaken in 31 villages and local people's perceptions of well-being and poverty indicators. This will help researchers target research and development interventions to the social groups who will benefit most from them.

clusters identified to complete more in-depth household case studies. Six major household types were identified, based on their livelihood activities (Table 24). It was found that most households in Khanasser are poor, earning less than US$2 a day. In general, households which practiced mixed cropping, livestock (mainly fattening) production and off-farm labor activities earned the highest per capita income. The worst off were those relying on labor alone and owning a limited number of livestock. The results are consistent with the farmers' own assessments of their well-being categories (Table 23). Livestock rearing and off-farm labor were identified as the major income-generating activities, as crop production accounted for 10-30% of cash income of most households. Overseas seasonal migration accounted for more than half of household earnings (56%), followed by earnings from national agricultural labor (29%), and from national non-agricultural labor (15%; Fig. 34).

The household typologies and livelihoods identified by the study will help researchers monitor the impact of research on different types of households, fine-tune technological options to better meet farmers' needs, and improve the livelihoods of the poor. Technological options include packages to improve small ruminant production since the 28,000 sheep and 1300 goats in the Valley make this an important economic activity for 70% of households. The productivity of barley, the main sheep feed, could be improved by using drought-tolerant barley varieties. Other technologies, such as alley-cropping drought-resistant saltbush (*Atriplex* spp.) shrubs with barley or vetch, can improve flock management, and the provision of small-scale facilities to improve the processing of dairy

Table 24. The six major types of household livelihoods identified in Khanasser.

Livelihood typology	Sub-category	Per capita income (US$/day)	Main livelihood activities
Wage-laborers	With farming	0.82	Mainly off-farm wage-labor and some crop production
	Herders	0.48	Mainly off-farm wage-labor plus livestock
Agriculturists	With off-farm labor	1.72	Crops, livestock (particularly sheep fattening), and off-farm labor
	Without off-farm labor	1.30	Mainly dependent on crops and livestock, particularly sheep fattening
Pastoralists	With off-farm labor	1.43	Rely on extensive livestock production and off-farm labor
	Without off-farm labor	1.15	Mostly livestock production

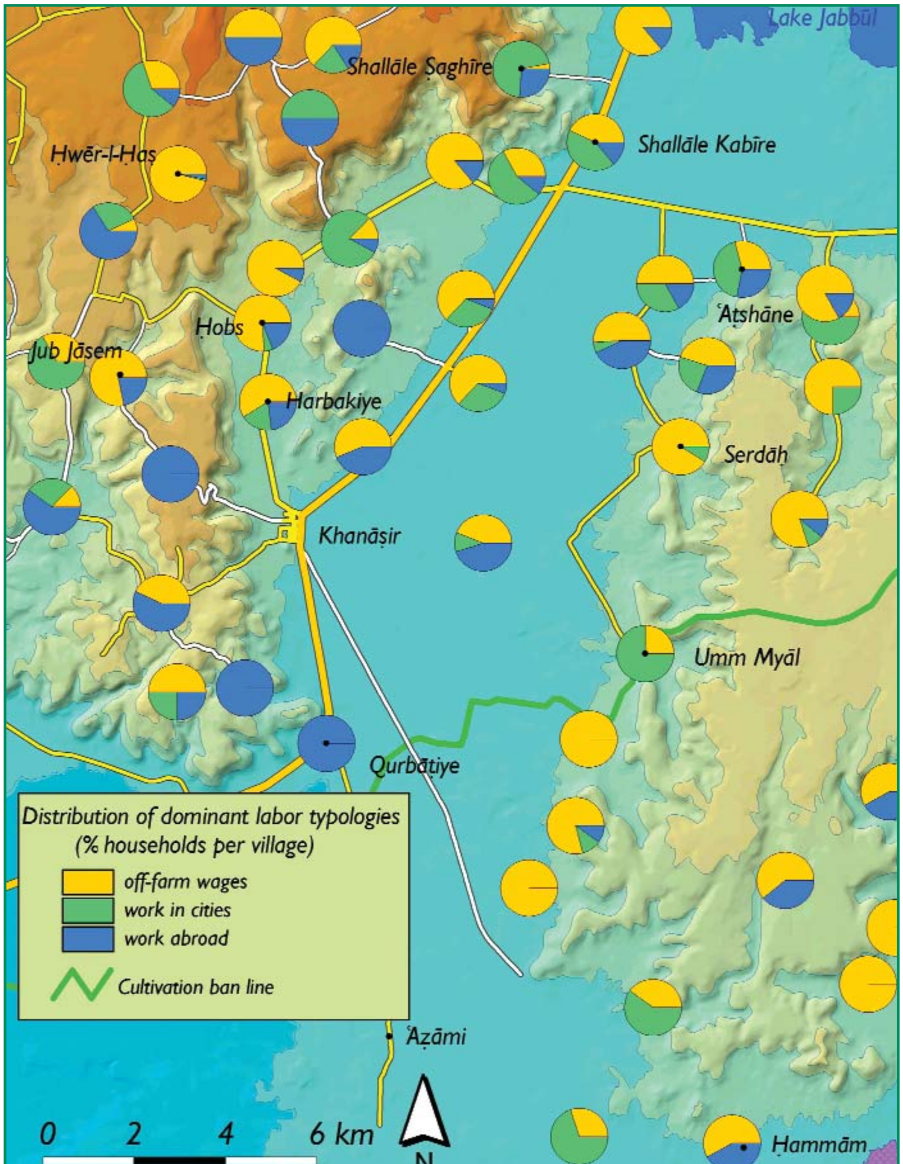


Fig. 34. The contributions of different off-farm employment sources to household incomes in Khanasser, Syria.

products, could increase the profitability of sheep production.

Sheep fattening is already a profitable enterprise, but institutional innovations (such as micro-credit organizations) would be needed to enable the poor to engage in this type of enterprise. Purely agricultural options also exist. For example, cumin, a new crop, generates a high income but is associated with high risks due to yield and price variations. Using water-harvesting techniques with olive trees can make use of barren hillsides, arrest soil erosion, and increase farm incomes while requiring only a minimal amount of labor. This could be an appropriate option for local communities with high levels of off-farm employment.

Rural livelihood analysis in three micro-watersheds in Yemen's mountains

ICARDA's research to improve rural livelihoods and reduce the degradation of Yemen's mountain terraces as part of its community-based integrated natural resource management (CB-INRM) program is helping Yemen's agricultural research institutions develop an impact-oriented, client-responsive approach. The enthusiasm of Yemen's Agricultural Research and Extension Authority (AREA) researchers is already making a mark on their selected watersheds. At the same time, the project is providing AREA with the opportunity to experience and evaluate CB-INRM approaches, and judge their value in improving the livelihoods of the rural poor. It is important to note, however, that successful CB-INRM research requires the support of a well-funded and managed research system. The fact that Yemen's agricultural research sector is seriously under-funded will make long-term change difficult to achieve.

To identify the exact needs of Yemen's rural communities, a participatory poverty assessment was used to determine the perceived livelihood categories of rural households, and the criteria that local people use to describe the level of well-being of different households. Key informants were asked to classify farmers in each village into one of four categories: 'very poor,' 'poor,' 'moderately well-off,' and 'well-off.' They were then asked to identify the criteria that are typically used to classify households into these different well-being categories (Table 25).

Table 25. Well-being categories and characteristics, as perceived by local people in the Al Qimma watershed, Yemen.

Well-being categories	Assets	Sources of income
Very poor	Landless	Agricultural wage labor, non-agricultural wage labor in towns
Poor	Small land area, some have sheep and goat, some have small shops	Agriculture (own farm), sharecropping, off-farm work: agricultural and non-agricultural wage labor in towns, trade, and remittances
Moderately well-off	Land, some own livestock, some have cars, flour mills, and shops	Agriculture (own farm), sharecropping, off-farm work: government jobs, non-agricultural wage labor in towns, trade and remittances
Well-off	Most own large land holdings (over 2 ha). Most own livestock, some own cars, mills, and shops	Agriculture (own farm), off-farm work: (government jobs), non-agricultural wage labor in towns, trade and remittances

Source: Rapid rural appraisal survey, 2002.

Researchers also conducted quantitative surveys to determine farmers' assets and the proportion of their income that was derived from different sources. Results showed that household incomes in Yemen's mountain communities are quite variable, with the poor having the least diverse income sources, and rendering them the most vulnerable (Fig. 35). The poorest were described as having few or no assets, mainly working for others or sharecropping. Because they have no, or very little, productive agricultural land, they depend less on agriculture and more on wage labor and non-agricultural incomes (Fig. 35). This means that institutional innovations and asset-building policies, such as schemes to enable the poor to acquire livestock, are needed to benefit the poorest, since they will not benefit directly from new production technologies. High-payoff agricultural technologies are essential, however, for the poor with limited agricultural assets. Such technologies include drip irrigation of trees, which involves efficient water use, and the introduction of high-quality seed of modern varieties of the food legumes grown in the area, such as green peas, fenugreek, and lentils. Relatively better off farmers with agricultural assets could benefit directly from the introduction of high-value horticultural crops, and improved agricultural practices such as effective soil, water, and pest management techniques. The establishment of effective links to the market is also an issue that needs to be addressed.

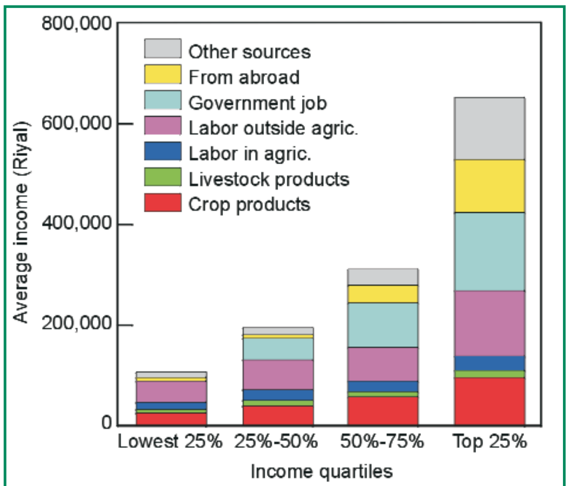


Fig. 35. Composition of the incomes of rural households in Yemen's mountains, grouped by income category or quartile (average of samples from three sites; 176 households interviewed in total).

Water scarcity was identified as the most critical issue in the study areas. Women spend much of their time fetching water, and the communities have developed complex water-management structures based on local knowledge. These include networks of channels that carry harvested surface runoff to distant fields during the rainy seasons, and seasonal springs with a network of diversion channels that carry water to small reservoirs and cisterns. These techniques support the area's limited irrigated agriculture, which consists of high-value crops, such as coffee, vegetables, and *qat*, a mild stimulant used in Yemen and East Africa. Cisterns are also used to store runoff for domestic consumption. Water-sharing mechanisms are also implemented based on traditional institutional arrangements, and these are working well. However, several limitations were identified.

Population growth, increased interest in off-farm employment, and male out-migration are all straining the traditional institutional arrangements which no longer provide adequately for the repair and maintenance of these water systems. Farmers listed help with improving their water systems as their first priority. Interest-free loans for developing water resources are available, but farmers are neither fully aware of the service nor effectively organized to access it. A huge divide exists between the resources that different national and provincial institutions provide for community development and the information and organizational capacity available to distribute them at the local level. It is essential that community organizations be developed to increase awareness of the available resources and reduce the related transaction costs. Such organizations could also serve as the link between research and extension.

The role of women was also identified as critical in the mountain communities. In terms of labor, women's contribution to sustainable livelihoods is substantially greater than that of men. Women handle most of the livestock-related jobs, including herding (which is mainly done by girls), rearing, feeding, collecting feed from the fields and *wadi*s, milking, and cleaning animal yards. Women and girls account for about 88% of such labor: boys provide the remaining 12%. Women are also responsible for preparing animal dung for fuel, fetching fuelwood and water, taking care of the children, and handling all domestic work. Women and girls also contribute about 31% of the labor for crop production and terrace repair. Research and development interventions should address the drudgery that is a regular part of women's daily life.

Prevalence of malnutrition in three livelihood systems in northwest Syria

Height measurement of a child in Yakhour village, Syria.

National-level data often fails to reveal the true extent of rural poverty. So, to identify those groups that are hit the hardest, empirical studies are needed of vulnerable households in marginal regions. Under-nutrition is a key indicator of rural poverty, and can have severe long-term effects on people's health. Therefore, ICARDA conducted a detailed study of the nutritional status of children in different livelihood systems in northwest Syria, which was completed in 2003.

The study covered 207 households, and considered 541 children under the age of 10 from three agricultural production systems: 'irrigated,' 'barley/livestock,' and 'olive/fruit trees.' Researchers used informal interviews, seasonal calendars, participatory characterization of households and food-frequency questionnaires, and measured the weight and height of children of different ages. By comparing these measurements with the international reference values recommended by the World Health Organization (WHO), they could then estimate the prevalence of stunting (statistically low height-for-age values), underweight children (low weight-for-age values), and wasting (low weight-for-height values). Results were also compared with measurements made of 199 children from a school in a middle-class neighborhood in the nearby city of Aleppo.

Stunting was found to be most prevalent in the barley/livestock group (23% of children were moderately to severely stunted; Fig. 36a), and far more girls than boys were stunted in this group. This indicates that the children in this group were suffering

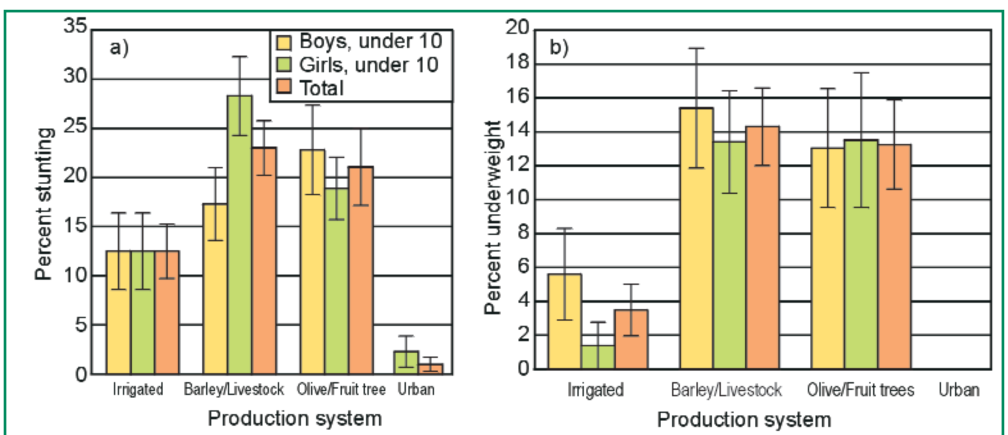


Fig. 36. Percentage of children under 10 years of age (a) with moderate and severe stunting and (b) who were underweight, in different agricultural production systems in northwest Syria and in a middle-class urban area.

from the long-term cumulative effects of poor nutrition and/or health. By contrast, the rate of stunting was much lower in the irrigated-agriculture group (12%), and in the urban group, it was only 1%, on average.

In the urban group, no children were underweight or wasted (Fig. 36b). Among the agricultural livelihood groups, prevalence of wasting was very low in the barley/livestock and olive/fruit tree groups, and zero in the irrigation group. The study highlighted both the nutritional status of children and the most affected households in different rural settings in Syria, thus providing strong social justification for policy action intended to help these households undertake viable economic activities. The methods used in this study provide a relatively easy, unobtrusive way of monitoring child nutrition, and should form part of rural health workers' training for wider application in similar environments.

Project 4.3. Property Rights and Resource Management in the Low-Rainfall Areas of North Africa and West Asia

Since 1995, the Mashreq/Maghreb (M&M) project, coordinated by ICARDA in partnership with IFPRI, has been working to foster the integration of improved and sustainable crop and livestock production systems in low-rainfall areas. Property rights were a focus of the project, as these can determine whether or not farmers will invest in more efficient and sustainable production systems. In 2003, analyses were completed on the effect of various property-right systems on different cropland, and rangeland-management systems and their profitability. Results suggest that granting farmers more complete property rights will promote access to credit and encourage the use of improved technologies and land-use practices. Also, work began on developing a new, multi-year bioeconomic model that will take into account the medium- and long-term decisions of farming and herding households. This will be a useful decision-making tool for use by policymakers, extension agencies, and researchers. In a separate study, researchers analyzed conflicts over land, forest, and water resources in six countries, and found that conflicts occurred more frequently when resources were under State management than when community collective ownership rights were recognized.

Cropland and rangeland management issues in the Mashreq and Maghreb region

In partnership with IFPRI and NARS, ICARDA's Mashreq and Maghreb (M&M) project is studying the effectiveness of property-right systems and institutional arrangements in the region, and evaluating their impact on the management of cropland. Focusing on the community, household, plot, and crop levels, the project is also assessing alternative institutional rangeland-management techniques and market-based options that could increase access to feed.

Cropland and the effects of property rights: input use and profitability

To address the need for efficient, equitable, and sustainable cropland use, the governments of Iraq, Jordan, Lebanon, and Syria (Mashreq countries) and Algeria, Libya, Morocco, and Tunisia (Maghreb countries) have introduced different land-tenure options. These affect cropland management and the welfare of farmers in different ways.

Morocco's government, for example, recognizes both customary private ownership rights (*Mulk*) and collective tribal rights. These accounted for 76% and 18% of cropland, respectively, according to a 1996 national survey. In Tunisia, by contrast, the government has privatized land rights and granted land titles. As a result, privately owned lands accounted for 90%, and collective lands 4% of the country's cropland.

It is generally thought that farmers with incomplete land rights (those who use the resource but not own it, or vice versa) will make less use of inputs and hired machinery than farmers with complete land rights (private ownership). Project researchers found this to be true in Morocco where farmers relied on family and hired labor to farm land held under incomplete land rights, but used mechanization and more inputs on land held under complete land rights. As a result, the profit margins gained per hectare from collective tribal lands and land 'appropriated' from State-owned

The care and maintenance of the health of the land hinges on land rights of the farmers. If they have a feeling of ownership, they protect it from degradation (*left*); if not, the land may be left to degrade and become unproductive (*above*).

areas (incomplete land rights) were much lower than those from rented fields and bought and inherited private fields.

In Tunisia, however, the results were less clear cut. Input use was not clearly related to the type of land rights (complete or incomplete) held by the farmer. Also, profit margins did not differ significantly between land-right categories. They did, however, differ significantly between crops grown. For example, profit margins per hectare were higher for vegetable than for cereal fields.

Two main conclusions emerged from the studies. First, Tunisia's privatization policies have removed the differential effects of land rights that arise from farmers being unwilling or unable to invest in land in which they do not have a 'stake.' Farmers now have similar opportunities for gaining access to credit and investing in their land. As a result, the main difference between farms was the extent to which farmers adopted new technologies and diversified their production systems.

Second, though the maintenance of collective land rights in the croplands may have been a good strategy in the 1920s, when population pressure was low and much land was available, the region's countries now need to improve the productivity of their lands through the use of inputs and mechanization and other forms of investment. To encourage this, full ownership should be granted to farmers.

Analysis of rangeland-management options

The region's governments have also introduced a variety of different rangeland-management options. These include tenure reforms (state ownership, collective rights and their privitization) and the institutional reorganization of pastoral communities (state management, cooperatives, and co-management), to improve the management of collective pastures. However, only limited efforts have been made to quantify the effects of these options on pastoral production systems and the costs and benefits of livestock production. The project is assessing whether or not the new options provide higher 'payoffs' than customary management systems.

Morocco is the only country in the region to recognize a customary management system based on collective tribal rights. The government formally recognized such rights in 1919, allowing tribes to delimit and title their lands in the names of their tribes, thereby giving them common property rights. This restricted the state's ability to manage the range. However, it was able to intervene to a limited extent in the 1970s, by creating 'pastoral perimeters' or delimited areas managed by government range managers. In the 1980s, a similar system of 'tribal cooperatives' was created on tribal lands. Unlike the pastoral perimeter system, tribal cooperatives respected customary tribal boundaries.

To assess the systems used in Morocco, the project considered three areas of the country: (i) the High Atlas, where customary institutions continue to effectively manage collective spring pastures; (ii) the Middle Atlas, where the pastoral perimeter system is used most; and (iii) the Eastern Atlas, where tribal pastoral cooperatives have been introduced. Rapid rural appraisals were conducted in transects through the three areas, and 325 households surveyed in depth. Econometric analyses were then used to determine the effect of an increase in herd size on gross income, feed costs, and profit margins.

- Under customary management in the High Atlas, increasing the size of a herd by an additional tropical livestock unit (TLU) had positive but not significant effects on gross income, feed expenditures, and profit margins per TLU. The most significant determinants of both gross income and profit margin were time spent on the range and range quality. Neither explanatory variable affected feed expenditures significantly.
- Under the 'pastoral perimeter' system of the Middle Atlas, increasing the size of a herd by one unit led to significant decreases in both gross income and feed expenditures per TLU, but had positive though not significant effects on profit margins. This means that people make more use of the range when they have larger herds which risks environmental degradation if range access is not well regulated. Moreover, being a member of a pastoral cooperative, growing forage, and 'giving' a part of one's herd to other herders under breeding contracts significantly reduced feed expenditures. By contrast, taking additional livestock under breeding contracts significantly increased feed expenditures.
- Under the 'tribal pastoral cooperative' management system of the Eastern Atlas, increasing the size of a herd by one unit led to a significant decrease in gross income, feed expenditure, and profit margin per TLU. However, the coefficient associated with feed expenditures was lower in this system than it was in the other two systems. Moreover, membership of the Moroccan Sheep and Goat Association had significant positive effects on gross income and profit margins.
- Overall, researchers found that livestock producers in tribal cooperatives have higher gross revenues and higher feeding costs per TLU than producers using the customary system. However, the profit margins of the two groups did not differ significantly. In the pastoral perimeter system, feeding costs were higher and profit margins lower than in the customary system.

Two main conclusions emerged from the study. First, both the pastoral perimeter and tribal cooperative systems offer incentives to increase herd size. This might be partly due to the allocation of subsidized feeds to herders, to reward them for improving part of their rangeland or leaving it ungrazed for two years or more to allow pastures to regenerate. Second, livestock producers operating under customary and tribal cooperative systems generated higher profits than those operating under pastoral perimeters.

Assessing the impacts of policy and technical changes: new bioeconomic models

A new project that builds on community models previously developed by the M&M project began in 2003. The Euro-Mediterranean Forum of Economic Institutes (FEMISE) project is funded by the European Commission, and involves collaboration between ICARDA and various national agronomic research institutes. These include INRA-Settat in Morocco, INRAA in Algeria, and INRAT in Tunisia. Scientific support is provided by IFPRI and two French institutions: Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), and Institut National de la Recherche Agronomique (INRA).

The project aims to build a recursive, dynamic model that can be used to simulate various bio-economic factors over a five-year period. This will help researchers understand the medium- and long-term decisions made by farming and herding households, especially their herd-management and labor-allocation strategies, and their investment in perennial crops, such as shrubs for improving soil fertility and controlling erosion, and olive trees. It should also help researchers better understand the behavior of producers faced with particular technical and economic constraints. Ultimately, the model is intended to act as a decision-support tool, helping decision-makers and extension agencies anticipate the impacts that policy or technical changes will have on productivity, livelihood conditions in the community (incomes and income distribution), and the sustainability of the natural resource base.

Researchers also plan to integrate people's off-farm activities and specific household characteristics into the model, placing particular emphasis on the way labor resources are allocated among men, women, and children. Common property resources will also be included in the model, as this will allow project staff to evaluate the effects of individual practices or institutional changes on the sustainability of common pastures. Finally, the scientists involved also aim to integrate farmers' attitudes towards risk into the model, thus helping them understand the decisions farmers make in uncertain environments.

In 2003, a number of data-collection activities were carried out in the different countries being studied. In Morocco, 85 households were surveyed in the Ait Ammar community. This follow-up survey was intended to update data and a community model previously developed by the M&M project. The management of grazing on the community's common pastures and the forms of association between herd owners and shepherds were also analyzed. This will help researchers assess the impact of different traditional and modern forms of association on natural resource management.

In Algeria, a second survey was also conducted of 60 households in the Sidi Frej community. Again, the purpose of this study was to update data collected in a previous survey and to calibrate a community model built by the M&M project. In addition, 12 participants attended a training workshop on modeling that was organized by ICARDA, with support from CIRAD, and conducted at INRAA. A study was also begun to assess the marketing of livestock and the *Opuntia* cactus, which can be used as an animal feed. This will be completed in 2004. Researchers will use the data to analyze the different market opportunities for the fruits and the fleshy pads of the cactus.

Forty households were also surveyed in Zoghmar, Tunisia to update data collected in a previous survey and to calibrate (for the medium term) a model that had already been built for that community. In addition, a livestock marketing survey was conducted. In Jordan, the project focused on developing a multi-periodic model for the Maikfeh community.

Land tenure, institutions, and conflict management

Conflicts between stakeholders can indicate institutional and market failures, and reveal property-right regimes that encourage inefficient, inequitable, and unsustainable resource-use practices. However, conflicts can also arise from attempts to reform inappropriate property-right systems and correct inequalities or improve the efficiency of resource access, control, and use. In both cases, therefore, it is important to (i) identify policy instruments that will enhance the performance of traditional or introduced institutions, and (ii) set up efficient conflict-resolution systems.

To address these issues, ICARDA and IFPRI analyzed conflicts that had arisen over land, forest, and water resources in three WANA countries (Jordan, Morocco, and Tunisia) and three Sahelian countries (Mali, Niger, and Senegal) in 2003. Researchers evaluated trends in natural resource use, as well as the different legal and institutional frameworks governing the management of land, forest, and water resources in the six countries. Additional case studies specifically considering conflicts over natural resources were also completed in Jordan, Mali, Morocco, Senegal, and Tunisia. With the exception of Jordan, these countries have all implemented different decentralization and reform policies, aiming to devolve greater managerial powers to individual communities.

Preliminary results show that the number of registered conflicts was higher in countries where resources especially forest and range resources were under State management than in countries where the collective ownership rights of communities were recognized. The study's results will be used to further understand the wider effects of resource-related policies, as well as the linkages between resource policies and conflicts.

Project 5.1. Strengthening National Seed Systems in CWANA

Development of a new, superior variety marks the end of a breeding effort, but the beginning of a long and difficult process of producing sufficient quantities of high-quality seed and distributing it to thousands of small-scale farmers. ICARDA's Seed Unit collaborates with national programs in CWANA to address seed-supply constraints and provide human-resource development for effective seed systems. In 2003, the Center continued to concentrate on Afghanistan's short- and long-term seed system requirements. An in-depth study in northern Afghanistan provided a thorough understanding of the systems currently in use. ICARDA also rebuilt seven research stations with facilities for variety selection and seed multiplication. These stations provide the foundation to rebuild Afghanistan's crop production systems and are already evaluating and multiplying a number of varieties and lines for farmers. Alternative vegetable and fruit crops, representing a diversity of new commercial opportunities, have been established in the station's nurseries. The Badam Bagh station, Afghanistan's main seed-health and seed-quality testing laboratory, was opened to address crop quality issues. ICARDA set up 25 decentralized village-based seed enterprises to provide farmers with easy access to improved seed.

Seed systems research for food security in northern Afghanistan

ICARDA conducted an in-depth study in rainfed areas in northern Afghanistan, funded by the International Development Research Centre (IDRC), to obtain a clear understanding of local seed systems with the aim of identifying suitable interventions that will strengthen informal seed systems by forging links with large-scale formal systems. Researchers conducted 500 household surveys and 12 focus-group discussions in 69 villages in three provinces (Baghlan, Badakshan, and Takhar) in Afghanistan to assess wheat, barley, chickpea, maize, flax and sesame production systems. This work was done in collaboration with the Aga Khan Development Network, Kunduz Rehabilitation Agency, Afghan Aid, Afghanistan Ministry of Agriculture and Livestock, ICRISAT and the Overseas Development Institute (ODI).

A farmer survey in progress in Afghanistan to collect information on sources of seed that the farmers use and how the seed supply system can be made more efficient.

The results of the survey disproved certain popular beliefs about the agricultural situation in Afghanistan. One common belief was that many farmers had been displaced from their homes, causing an interruption in agricultural activities. However, a majority of households reported uninterrupted agricultural activities over the past 10 years, although they were affected by drought and insecurity. The focus-group discussions revealed considerable variation in the levels of displacement in different villages, ranging from no displacement at all in one village in Kunduz province to total displacement in another village in Takhar province. Farmers who discontinued their agricultural activities did so because of war, drought or a combination of both.

A loss of wheat varieties occurred over time, but this was as a result of new varieties replacing the old, rather than the effects of drought or war. Nearly half of the participants in focus groups reported a loss or abandonment of local varieties and a few old improved varieties because of low yields, changing agroecological conditions, low resistance to disease and drought, or replacement by newer varieties. In particular, a high incidence of pests and diseases as well as increasing susceptibility could be a strong force in promoting varietal replacement and diversity.

Farmers estimated that their own production would meet their household food needs for 11 months of the year, as opposed to only 7 months in the previous year. This substantial improvement in household food security is largely due to the end of the drought. Any significant improvement in productivity through the use of better varieties, high-quality seed or efficient input use could close the food gap and provide households with a surplus of products for sale.

The seed systems used in the rainfed areas of northern Afghanistan are informal in nature and characterized by few location-specific varieties for each crop, no

Rehabilitated research station in Baghlan.

improved varieties for any crops other than wheat and barley, and poor seed quality—all of which contribute to low yields. The study recommends a range of measures that will give farmers a wider choice of varieties, enhance seed quality, and improve productivity.

Connecting farmers to new crops, approaches, and technology

Research stations–the foundation for agricultural development

Agricultural research stations provide the means for crop improvement, technology transfer, training and educational opportunities, and initiating small agri-business developments. Unfortunately, over the past 20 years, most of the 22 agricultural research stations in Afghanistan were confiscated by warlords, looted or destroyed. This loss is immeasurable because it was at these regional research stations where farmers assessed new crops and received information on improved crop varieties, better seed multiplication techniques, fertilizer use, pesticide application, and irrigation water management. The Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), led by ICARDA, is taking steps to correct this situation.

Within the framework of activities of FHCRAA, ICARDA with funding support from USAID, has rehabilitated research stations in the provinces of Kabul (the Darul Aman Research Station), Baghlan (Pushei Shan Station), Kunduz (Central Station and Chardarah Station), Takhar (Baghzekhira Station and Forme Labedaria) and Nangarhar (Shishambagh Station). Damaged buildings were repaired and land was once again cultivated. Farm machinery, meteorological equipment, and seed cleaning and treatment machinery were provided and wells were dug deeper where drought had dried them up.

Adaptive research on seed multiplication of existing best-performing Afghan varieties has been initiated at the research stations. Also, small quantities of seed of improved varieties and lines that are carefully selected at ICARDA's headquarters are evaluated and multiplied for farmers' use. A participatory approach allows farmers to select improved varieties that perform best in different agroecological conditions.

The newly established agricultural research stations will also serve as the base from where alternative crops and production techniques will be distributed to farmers. These alternative systems represent a balanced and healthy diet for Afghans as well as new employment opportunities. For example, horticultural crop nurseries will enable farmers to replant their orchards and benefit from excellent water-use efficiency, and this in turn will allow them to sell their value-added produce in regional and global markets. With the assistance of IPGRI, research stations are now establishing horticultural nurseries with grape vines, as well as almond, peach, pear, apricot, walnut, apple, mulberry, olive, fig, pomegranate, lemon and orange trees. The nurseries will be self-sustaining and will sell seed and saplings to Afghan farmers.

The FHCRAA is increasing farmer crop choices by supporting dairy, meat and hide production in addition to vegetable, food legume, forage and feed grain production. Seeds of carrots, onions and turnips are now produced at the Kunduz agricultural station, while rice and mung bean seeds have been distributed, along with appropriate fertilizers, in Baghlan, Kunduz, and Takhar. The CIMMYT maize program is also distributing improved open-pollinated maize populations. CIP has produced, graded and treated 30 tonnes of virus-free adapted seed potatoes and is evaluating new varieties. Seed potatoes are being produced in disease-free areas such as Nangarhar during the winter season for planting in Kabul, Wardak, and Bamyan in the spring.

Seed assurance services – the key to quality seed and planting material

Within the FHCRAA, ICARDA has assisted the government of Afghanistan in establishing a number of seed testing stations to


The Badam Bagh research station– before *(left)*; after rebuilding *(right)*.

ensure the quality of seed that is marketed to farmers. Two main stations (Badam Bagh and Jalalabad) and six satellite stations have been equipped and made operational. The inauguration of the Badam Bagh station in Kabul as the national seed-testing station by the Minister of Agriculture in July 2003 marked the historic reintroduction of up-to-date seed-testing technology in Afghanistan. The Badam Bagh station houses the only seed health and quality testing laboratory in Afghanistan, and will implement the Code of Conduct for Seed that was developed by the FHCRAA and adopted by the Acting Interim Government of Afghanistan. The Code of Conduct sets the quality standard for seed that is imported into the country and requires that seed should be certified, accurately labeled, and free of pathogens and pests. This laboratory will pave the way for Afghanistan to re-enter the global economy.

Farmers thrash and clean the seed they produced themselves.

Village-based seed enterprises – the approach for decentralized seed production

In Afghanistan, where infrastructure has been seriously damaged, creating a decentralized seed production system provides a greater advantage over a centralized system. The village-based seed enterprises (VBSEs) used in a decentralized system provide farmers with easy access to new crop varieties and technologies. As a first step in developing VBSEs, a training course entitled 'Seed Production Technology and Management' was conducted in Kunduz in June 2003. Twenty progressive farmers from Baghlan, Kunduz, Kapisa, Nangarhar, and Takhar (provinces that form the 'bread basket' of Afghanistan) were trained in the establishment and management of small seed enterprises.

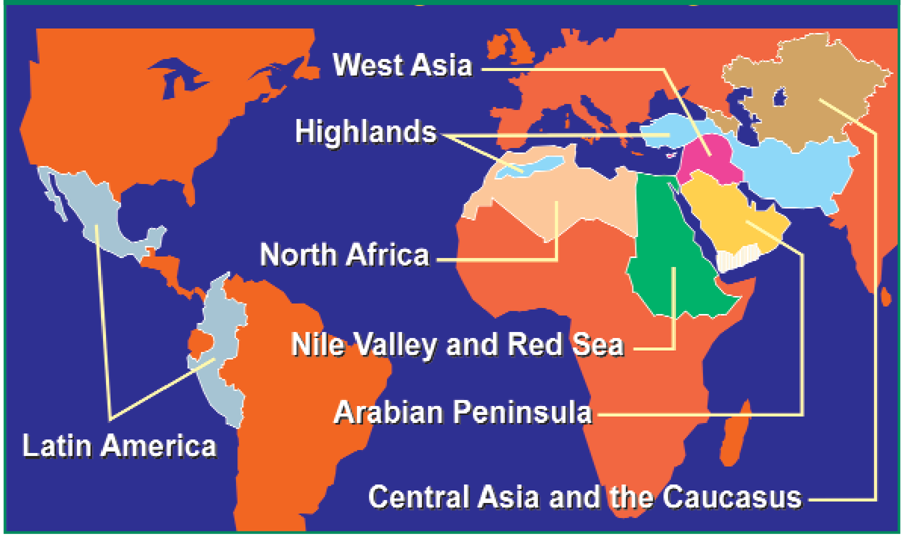
A total of 25 VBSEs were initiated in Baghlan, Kabul, Kapisa, Kunduz, Nangarhar, Takhar, and Wardak provinces. Each VBSE has a farmer-leader who heads a team of ten farmers who produce seed in the selected districts. The VBSE system represents the key to developing a robust, yet stable rural economy. Increased agricultural productivity and incomes through effective linkages between producers, processors, and markets is the cornerstone of this program.

International Cooperation

ICARDA cooperates internationally with NARS, donors, and advanced research institutions to pursue its research and training agenda. Activities that promote partnerships with NARS within ICARDA's mandated region, including networks (see Appendix 6) and capacity building, are outlined below. Collaborative projects with advanced research institutes and regional and international organizations 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 of CWANA cover the entire research spectrum, from basic and strategic research to applied and adaptive research and, finally, to technology transfer. ICARDA promotes its partnership with NARS through seven Regional Programs across the geographic subregions that share similar agroecologies: North Africa, Nile Valley and Red Sea, West Asia, Arabian Peninsula, Highlands, Central Asia and the Caucasus, and Latin America.

ICARDA's Regional Programs



North Africa Regional Program

The North Africa Regional Program (NARP) operates through ICARDA's regional office in Tunisia serving Algeria, Libya, Mauritania, Morocco, and Tunisia. Liaison Offices have been established in Morocco and Algeria. The objectives of the program are to contribute to poverty alleviation, natural resources conservation, enhancing productivity of crops and animals, human resources capacity building, and networking in the region.

Collaborative projects

In 2003, the program implemented many collaborative projects. Regional-level projects included the "Sustainable Management of the Agro-Pastoral Resource Base in the Maghreb," funded by the Swiss Development Cooperation (SDC); "Obstacles to Technology Transfer to the Small and Medium Farmers in the Arid and Semi-Arid Zones of the Maghreb," supported by the Euro-Mediterranean Forum of Economic Institutes—FEMISE; "Optimizing Soil Water Use" within the framework of the CGIAR Systemwide Program on "Soil Water and Nutrient Management (SWNM);" and the regional program to "Foster Wider Adoption of Low-Cost Durum Technologies," funded by IFAD.

National-level collaborative projects included the "Pilot IPM Site in Morocco" within the framework of the CGIAR Systemwide Program on "Integrated Pest Management (IPM)," and "Functional Genomics of Drought Tolerance in Chickpea in Tunisia," supported by BMZ.

Six bilateral projects funded by USDA-Tunisia, with ICARDA associated as a partner to provide backstopping, continued to be implemented. Two of these are implemented in partnership with IRA Medenine—"Economic and Cultural Value of Herbal, Aromatic, and Medicinal Plants," and "GIS for Watershed Management in the Arid Regions of Tunisia." Others are: "Research on Improving Productivity of Oats as Priority Forage Species;" "Partnership to Improve Rural Livelihoods in North Africa and West Asia through Strengthened Teaching and Research on Sheep and Goat Production;" "Biological Control of Weeds with Plant Pathogens;" and a sub-regional "Expert Consultation on Biotechnology in Algeria, Morocco, and Tunisia."

In addition, NARP started the implementation of a bilateral research-development project called "Rapid Impact Program on Research and Extension in Mauritania," with support from CIDA. Also, implementation of five new bilateral projects for Morocco started in 2003. The projects are in biotechnology, crop improvement, genetic resources and genebanks, IPM, agro-ecological characterization, and GIS.

Seven project proposals were developed in partnership with NARS in 2003. Proposals for which funding has been obtained are: "Watershed/GIS Tunisia," funded by USDA in collaboration with Purdue University; and "Improving the Livelihoods of Rural Communities and Natural Resource Management in the Mountains of the Maghreb Countries of Algeria, Morocco and Tunisia," funded partially by SDC.

Participants of the Morocco–ICARDA annual coordination meeting held in Rabat on 29-30 September 2003.

Workshops and coordination meetings

NARP co-organized three major workshops: (i) an expert consultation on "IPM for *Orobanche* in Food Legume Systems in the Near East and North Africa (NENA)," in collaboration with INRA and FAO, in Rabat, Morocco, in April, (ii) a national workshop on the "Livestock and Rangeland Knowledgebase," in collaboration with INRA and IFAD, in Oujda, Morocco, and (iii) a regional workshop on the "Use of GIS and Remote Sensing in Agro-Pastoral Resource Management," in collaboration with INRA and SDC, in Oujda, Morocco.

NARP regional coordinator and scientists participated in several international and regional workshops. These included the (i) "Inter-Academy Council (IAC) Workshop on Science and Technology in North Africa," held in Rabat, Morocco; (ii) "Third Euro-Mediterranean Forum of Economic Institutes," held in Marseilles, France, at which a paper entitled "Vulnerabilities of Farming Systems in Arid and Semi-Arid Areas in Maghreb: Hypotheses and Methods" was presented; (iii) "Supplemental Irrigation in North Africa," organized by FAO in Tunisia; (iv) "Benchmark Rainfed Agriculture," held in Morocco; (v) "Aromatic and Medicinal Plants in the Mediterranean Region," organized by the EU and the University of Monastir, Tunisia; and (vi) "Expert Consultation on Medicinal Plants in North Africa," organized by IUCN.

Participants of the workshop on "Livestock and Rangeland Knowledgebase," held in Oujda, Morocco, 21-22 October 2003.

National coordination meetings were held in Algeria, Libya, Morocco, and Tunisia to review results of collaborative research and develop plans of work for the future. There was an increase in the participation of scientists from the different NARS in each country. The Coordination meetings were attended by more than 200 scientists, research managers, and extension agents, in addition to representatives from FAO, OSS, UNDP, IRD, AOAD and NGOs.

New partnership agreements

A new agreement was signed with the Ministry of Agriculture and Rural Development in Algeria, under which ICARDA will backstop the Algeria Rural Development Plan (PNDAR). A liaison office for ICARDA, fully supported by the NARS, was opened in Algeria in

October to strengthen the partnership and facilitate coordination within the country.

Human resource development

A two-week training course on "Participatory Community Approaches, Survey Methodologies and Data Collection and Analysis" was conducted by NARP in Morocco in collaboration with INRA Morocco. Twelve Mauritanian scientists participated in the training which was conducted as part of the project "Rapid Impact Program on Research and Extension in Mauritania," funded by CIDA. Within the framework of a new project "Agro-Pastoral Development and Local Initiatives Promotion Program in the South-East (PRODESUD)," funded by IFAD, NARP scientists trained project personnel on the community participatory approach. This was based on ICARDA's experience from the "Development of Integrated Crop/Livestock Production Systems in the Low Rainfall Areas of West Asia and North Africa," project.

Technical assistance

Within the framework of the IFAD-funded program on "Accelerated Project Performance in North Africa," ICARDA provided technical assistance to the following projects: (i) "Integrated Agricultural Development in Siliana" and "Integrated Agricultural Development in Zaghouane," in Tunisia—on monitoring, evaluation, impact assessment, alternative feed resources, and enhancing local institutions; and (ii) mountain and rural development projects in eastern Morocco—on sociology, local institutions, and rangeland management. ICARDA also provided technical backstopping to the IFAD-funded "Agro-Pastoral Development and Local Initiatives Promotion Program in the South-East," to institutionalize the community participatory approach within the project.

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 through the improvement of the productivity and sustainability of production systems, while conserving natural resources and enhancing the research capacity of national scientists in Egypt, Ethiopia, Eritrea, Sudan, and Yemen. NVRSRP coordinates ICARDA's activities and several special projects in the member countries.

Collaborative projects

The collaborative projects within the NVRSRP include: "Food Legumes and Cereals Improvement in Egypt," "Transfer of Improved Production Packages for Wheat and Legumes in Sudan and Ethiopia," "Control of Wild Oats in Cereals and other Winter Crops in Egypt," "Strengthening Client-Oriented Research and Technology Dissemination for Sustainable Production of Cool-Season Food and Forage Legumes in Ethiopia," "Natural Resources Management in Egypt," the ICARDA/AGERI project on "Identification of Resistance Genes in Cereals to Abiotic Stresses," and the ICARDA/CLAES project on "Upgrading Faba Bean and Wheat Expert Systems in WANA."

Several projects in the NVRSRP countries continued to be managed from ICARDA headquarters, covering such areas as integrated pest management in faba bean (Egypt), integrated cereal disease management (Eritrea), grasspea improvement (Ethiopia), barley participatory breeding (Yemen and Egypt) and mountain terrace conservation (Yemen).

In addition, NVRSRP contributed to the development of several concept notes on potential collaborative projects in the region for the approved Challenge Program on 'Water & Food.' One of them "Improving Water Productivity of Cereal and Food Legumes in the Atbara River Basin of Eritrea" was approved for funding.

Workshops and coordination meetings

A regional workshop on "Integrated Control of *Orobanche* and Viral Diseases in Egypt" was organized jointly with the Agricultural Research Center (ARC) of Egypt in Fayoum in

Participants of the regional wheat and food legumes traveling workshop in Egypt.

September. It was attended by 40 participants from Egypt, Lebanon, Morocco, Sudan, FAO, GTZ, ICARDA and IITA, as well as farmers from the Fayoum governorate.

In collaboration with the Central Laboratory for Agricultural Expert Systems (CLAES) in Egypt, ICARDA organized a regional workshop on "Utilization of Expert Systems in Agricultural Research and Production" in October. Twelve senior officials from Egypt, Ethiopia, Iran, Kazakhstan, Palestine, Qatar, Saudi Arabia, Sudan, Syria, and Yemen participated in the workshop.

ICARDA also co-organized a regional workshop on "Quality Assurance in Seed Testing" at the Giza Seed Testing Station of the Central Administration for Seed Certification and Testing in Cairo. Participants included senior managers of the most active seed testing laboratories in Afghanistan, Algeria, Egypt, Jordan, Morocco, Pakistan, Syria and Turkey.

The World Bank and ICARDA organized a consultation workshop on "Rural Development and the Role of Science and Technology in the CWANA Region" in Cairo, Egypt, in February. Participants from 26 countries included leaders and representatives from the agricultural sector and research organizations, NGOs, farmers' associations, civil society organizations, and the private sector. Representatives of donor agencies (FAO, GTZ, UNEP, WB and EU) and experts and scientists from the CG Centers and international and regional organizations (AOAD and ACSAD) also attended.

More than 130 researchers, scientists, policy makers, extensionists and representatives from different institutions participated in the "Second National Food Legumes Workshop" in Ethiopia, cosponsored by ICARDA.

From left, Mr Semere Amlesom, Eritrea; Dr Magdy Madkour, Egypt; Dr Mohan Saxena, ICARDA; Dr Demel Teketay, Ethiopia; Prof. Dr Elsadig Suleiman, Sudan; and Dr Ismail Muharram, Yemen, at the opening session of the Nile Valley and Red Sea Regional Program's thirteenth regional coordination meeting held at ICARDA headquarters, 13-16 October 2003.

The annual national coordination meetings were held in Egypt, Ethiopia, Sudan and Yemen. For the new partner, Eritrea, the first Eritrea/ICARDA coordination meeting was held in Asmara in October, and was attended by more than 90 scientists, researchers and extenstionists from the National Agricultural Research Institute (NARI), University of Asmara, Ministry of Agriculture, NGOs, Virginia State University, Danish Institute of Agricultural Sciences, Risø National Laboratory of Denmark, ICARDA and other agricultural development agencies. A large number of scientists and research managers from the respective national programs and collaborating universities, and from ICARDA participated in the meetings. Emphasis was put on transfer of improved technologies developed using the community approach.

The thirteenth NVRSRP regional technical coordination meeting was held in October at ICARDA headquarters in Aleppo, Syria. Thirty-seven scientists from the five countries and senior scientists from ICARDA attended the meeting. The DGs of the NARS of Egypt, Eritrea, Ethiopia and Yemen and Deputy Director General of ARC, Sudan headed their respective delegations.

NVRSRP Regional Coordinator participated in several important international and regional workshops/meetings. These included the (i) "Sustainable Strategies for Irrigation in Salt-Prone Mediterranean Regions: A Systems Approach," held in Cairo, Egypt; (ii) "Sub-regional Workshop on Science and Strategies for Improved Agricultural Productivity and Food Security in North Africa," organized by the Inter-Academy Council (IAC), AARINENA, and Hassan II Institute of Agronomy and Veterinary Medicine in Rabat, Morocco; (iii) "Fourth Session of the General Assembly Joint Committee on Environment and Development in the Arab Region;" (iv) "Fourteenth Session of the Steering Committee for Desertification of Technical Commission of the Council of Arab Ministers Responsible for the Environment (CAMRE);" and the (v) "Second Mediterranean Conference for Agricultural Research Cooperation," held in Cairo, Egypt.

Human resource development

NVRSRP organized a regional specialized training course on "Participatory Research Methods and Community Approach and Characterization" in Cairo, Egypt, in April. It was part of the IFAD-funded

NVRSRP project. Thirteen scientists from Egypt, Ethiopia, Sudan and Yemen attended the course.

An in-country training course was held in Eritrea in September on "Cereal Diseases and Integrated Disease Management." It was attended by 24 participants from research and extension institutions. Coordinated by ICARDA, in collaboration with IAV-Hassan II in Morocco, Risø National Laboratories of Denmark, and the Danish Institute of Agricultural Sciences, the course was part of the Integrated Cereal Disease Management Project (ICDM) that ICARDA is implementing in Eritrea.

Scientists from Egypt, Ethiopia and Yemen participated in a traveling workshop in March in Egypt. They visited demonstration plots of improved technologies in farmers' fields in Fayoum, Sakha and Nubaria. This was followed by another traveling workshop on barley production improvement in Egypt in April, in which 43 scientists, extensionists, and farmers participated. They visited farming activities related to barley production in the Governorates of North Sinai and Kafr El-Sheikh. Both workshops were conducted within the framework of the IFAD-funded NVRSRP Project.

Technical assistance

ICARDA scientists provided technical assistance to the Matrouh Resource Management Project (MRMP) in participatory barley breeding. The scientists visited the project to follow up on the field assessment of genetic material provided by ICARDA and planted under farmers' conditions and to assist the project team in preparing for the harvest. Assistance was provided to Faculty of Agriculture, University of Khartoum in upgrading its library.

Participants in the fifth regional technical and planning meeting of the GEF/UNDP Dryland Agrobiodiversity Project, held in Beirut, 3-4 September 2003.

Interregional cooperation

A delegation of scientists from the Chinese Academy of Agricultural Sciences visited NVRSRP in September. They expressed interest in initiating cooperation with Egypt through ICARDA's collaborative projects particularly in faba bean improvement.

NVRSRP and APRP facilitated the visit of two scientists from Afghanistan to the facilities of the Central Laboratory for Agricultural Climate (CLAC) to familiarize them with the Egyptian experience in protected agriculture.

The Director General of SPII, Iran, visited Egypt to discuss possible cooperation between the concerned Egyptian institutions and SPII.

A delegation from the Barani Project in Pakistan, consisting of the Director of the Soil and Water Conservation Research Institute (SAWCRI) and a senior researcher, visited research institutes of ARC, modern private farms in the newly reclaimed lands, and Marsa Matrouh resource management project in Egypt. They also visited the department of agronomy and soil science at Ain Shams University, Cairo.

West Asia Regional Program

The West Asia Regional Program (WARP) based in Amman, Jordan, works in partnership with the NARS of Iraq, Jordan, Lebanon, the Palestinian Authority, and Syria to enhance productivity of crops and rangelands in the dry areas. In spite of the prevailing difficult situation in Iraq and Palestine, ICARDA's activities in these countries have continued in the areas of capacity building, exchange of germplasm, scientific visits, and developing plans for the rehabilitation of the agricultural sectors. The major collaborative research project in the region is the GEF/UNDP-funded "Conservation and Sustainable use of Dryland Agrobiodiversity." There are other collaborative activities coordinated directly by the scientists at ICARDA headquarters for Syria and Lebanon.

The Dryland Agrobiodiversity Project

This project, now in its fourth year, continued its activities in Jordan, Lebanon, the Palestinian Authority, and Syria, of promoting the conservation and sustainable use of landraces and wild species of global importance originating from the Fertile Crescent. In 2003, the project focused on consolidating the achievements and impacts, and increasing local-community participation (see Project 3.3).

Workshops and coordination meetings

The fifth regional technical and planning coordination meeting of the GEF/UNDP Biodiversity Project was held in Lebanon in September. It was opened by the Ministers of Agriculture of Lebanon and Syria, and attended by representatives of GEF and UNDP, Directors General of national research institutes, national project managers and scientists from the four countries, and from ICARDA, ACSAD, and IPGRI-WANA. Participants expressed satisfaction with the achievements of the project in putting in place the framework for a sound community-based agrobiodiversity conservation approach. The regional steering committee meeting was held afterwards.

ICARDA organized a sub-regional workshop on "Declaring the *Badia* Benchmark Research Site in Jordan" at NCARTT headquarters in Amman in October, funded by AFESD and IFAD. More than 50 participants from NCARTT, the Ministry of Agriculture, universities, the Higher Council for Science and Technology, representatives of farmers and NGOs participated in the workshop. Participants reviewed the characteristics of the *badia* in WANA and the strategy for *badia* development in Jordan. They also visited potential sites in Muwaqqar, Mafraq, and Karak regions, and held discussions with local communities.

The ninth Iraq/ICARDA biennial coordination meeting was held in Amman, Jordan in November, and was attended by 12 Iraqi scientists led by the First Under-Secretary of the Ministry of Agriculture, Dr Basil Dalali. Representatives from the Ministry of Environment, the Universities of Baghdad and Mosul, the Research Institute IPA and the Institute of Science and Technology also participated. ICARDA Director General led a team of seven scientists from the Center. Representatives from USAID, JICA, and FAO attended the opening session. Participants were pleased with ICARDA's collaborative activities to rehabilitate the agricultural sector in Iraq in the past two years, which included the continuous provision of breeding nurseries of cereals and legumes, the initiation of participatory breeding for barley, the survey of insects and diseases of cereals, the assessment of economic impacts of supplemental irrigation and of technologies promoted within the Mashreq/Maghreb project, on-farm water-use efficiency, agroclimatic characterization, and initiation of GIS database. Agricultural research activities to be implemented in the next two years were discussed.

Human resource development

The Agrobiodiversity Project organized seven regional courses and 38 national training activities. More than 1430 farmers, researchers, and extensionists participated in the training activities, 400 of whom were women. Thirteen students obtained MSc degrees, and most of them are now working with the project. Traveling workshops for 21 women and 14 herders enabled participants to share experiences during their visits to project sites in Jordan, Lebanon, ICARDA headquarters, Syria, and many income generating activities of different projects.

ICARDA organized training for 10 Iraqi scientists at its headquarters, sponsored nine others to participate in international and regional conferences and workshops, and carried out more than 50 literature searches for researchers and university students. Two ICARDA scientists visited Iraq and two Iraqi scientists joined ICARDA to work, respectively, on water and socioeconomic issues.

Arabian Peninsula Regional Program

The Arabian Peninsula Regional Program (APRP), based in Dubai, coordinates ICARDA's activities in Bahrain, Emirates, Kuwait, Oman, Qatar, Saudi Arabia, and Yemen. Collaborative activities include research, capacity building, and human resource development in water resource management, forage production and rangeland management, and protected

Participants of the regional technical coordination meeting of APRP, held at ICARDA headquarters in December 2003.

agriculture. Major emphasis is placed on strengthening national institutional and human resource capacity, technology transfer and information technology, and networking. APRP is funded by AFESD, IFAD, and the OPEC Fund.

Collaborative research

To improve irrigation management of field crops in the Arabian Peninsula, fully automatic weather stations have been established in each country under a special agreement with APRP. The necessary equipment for networking these stations has also been provided. Data are collected on a regular basis and the irrigation management software is being developed. Water-use efficiency for the production of some vegetable crops, under surface and drip irrigation, has been studied in Bahrain in three locations. The results showed the advantages of the drip system over surface irrigation in water saving and yield. In Yemen, a study on the utilization of water dams and reservoirs in the highlands showed the need for regular record keeping of the amount of annual floods reaching the dams, and of the status of underground water.

Utilization of indigenous species as alternative forage plants is one of the major themes in the 'Forage Production and Rangeland Management' work in APRP. Studies to identify priority indigenous grass species continued in the UAE, Bahrain, the Sultanate of Oman, and Saudi Arabia. In the Al-Jouf area of northern Saudi Arabia more than 10 tonnes of native shrub seeds of 40 species were produced. Experiments carried out by APRP in the Al-Jouf covered (i) transplanting native shrubs under natural conditions with supplementary irrigation, (ii) comparison of two different methods of rangeland reseeding, and (iii) water-use efficiency of *Medicago sativa* in comparison with the local shrub *Atriplex leucoclada*. The results showed that (i) native range species adapted better to lower moisture content situations, and only a small amount of water provided at the time of planting was sufficient to establish the range shrubs; (ii) naturally distributed species were better adapted to transplanting, while perennial grass species needed reseeding to rehabilitate rangelands; and (iii) *Medicago sativa* had highest productivity in conditions of high moisture content, whereas *Atriplex* performed better under low moisture supply and remained productive even when the amount of water decreased to 6 mm in the root zone.

Seed multiplication of important forage grasses also continued in Yemen. *Adropogon barbanoides*, *Cenchrus ciliaris* and *Pennisetum thunbergii* are the most important range/forage species identified earlier by AREA-Yemen and are being multiplied at the North Highland Research Station, Al-Erreh.

A soilless vertical growing system for the production of cash crops under protected conditions was established in Oman by ICARDA working with Omani scientists. The technique offers a way of improving water-use efficiency and obtaining better water and fertilizer management in crop production.

Integrated Production and Protection Management (IPPM), a package of simple techniques and practices to provide greenhouse growers with environment-friendly crop protection without relying on hazardous agro-chemicals to produce high quality crops, has been introduced by APRP to the different research stations of the AP countries and adopted by growers. Use of insect-proof netting and hotspots control in an IPPM house eliminated aphids, leaf miners, and spiders, and only one spray of aphidicide was applied to control aphids as compared to the 'control' greenhouse where 10 sprays had to be applied during the season. In collaboration with the Agriculture Research and Extension Authority (AREA) cultivation of cash crops in greenhouses was introduced to farmers in the mountain terraces of Yemen, because a careful assessment of the socioeconomic characteristics of these production systems had revealed that there was a need to diversify the sources of income for the farmers by introducing high value crops. A Protected Agriculture project was started two years ago with three green houses, but the number has increased rapidly to fifteen. The Project has particularly helped the women farmers to earn additional income.

Workshops and coordination meetings

The regional technical coordination meeting of APRP was held at ICARDA headquarters, Aleppo, Syria in December, and brought together over 40 scientists from all the Arabian Peninsula countries. Over 35 scientific papers were presented and discussed and plans for the future were elaborated.

Several regional seminars and workshops were organized by APRP in the UAE. These included the (i) "Participatory Breeding for Stressful Environments," (ii) "Information Technology and its Effect on Improving Water-use Efficiency," (iii) "Integrated Pest Management," and (iv) a sensitization workshop on "ICARDA activities in Arabian Peninsula." APRP also conducted a workshop to review activities of ICARDA in the countries of Arabian Peninsula, with special emphasis on Saudi Arabia.

ICARDA sponsored scientists from AP countries to participate in the "Global Forum for Agricultural Research (GFAR)" meeting held in Dakar, Senegal, in May, and the "Seventh International Conference on Development of Dry Lands," held in Tehran, Iran, in September.

Human resource development

During the year, 21 researchers from the Arabian Peninsula countries participated in different training programs organized by ICARDA. These included: "Management of Water Resources and Improvement of Water-Use Efficiency in the Dry Areas," "Scientific Writing and Data Presentation," "DNA Molecular Marker Techniques for Crop Improvement," "Electronic Document Management and the Use of Web AGRIS Tools for Database Management on the Web," the "Regional Training Workshop on Participatory Research Methods and Community Approach and Characterization," and "Utilization of Expert Systems in Agricultural Research and Production."

An on-the-job training program on greenhouse management was organized by APRP in collaboration with the Arab Qatari Agriculture Production Company (AQAPC) for two Yemeni researchers from the Ministry of Agriculture and Irrigation. The participants spent two months in the modern farm of AQAPC in Qatar getting hands-on training.

Highland Regional Program

The Highland Regional Program (HRP) promotes agricultural production in the highland areas of Afghanistan, Iran, Pakistan and Turkey, as well as the Atlas mountain range in Algeria, Morocco, and Tunisia, and the highland areas in Central Asia and the Caucasus. ICARDA project staff are located in Iran and Afghanistan, while work in Turkey is handled from the headquarters.

Iran

Collaborative research

ICARDA scientists, along with their Iranian partners in Dryland Agricultural Research Institute (DARI), carried out collaborative experiments on germplasm (barley, lentil, chickpea, forage legumes) improvement and natural resources management, including soil fertility, tillage, and supplementary irrigation. More farmers adopted the improved technology for wheat growing developed by the collaborating program leading to an increase in production levels. The technology was adopted by farmers on an area of over 60,000 ha in four provinces as opposed to 4,000 ha in the previous season. Despite the terminal drought that prevailed in most of rainfed areas, about 12.5 million tonnes of wheat was harvested, enough to meet nearly 90% of the country's needs.

Farmers and researchers discuss the performance of a new wheat production technology in a farmer's field in Shirvan in northeast Iran.

Several breeding lines of cereals and legumes are candidates for release in 2004. These include: chickpea lines FLIP 90-96 and FLIP 93-93 (ii) lentils ILC 590 and FLIP 92-12L (iii) winter wheat line Fenkang15/Sefid and spring wheat line Desconocido-7 and (iv) winter barley line Yesevi and spring barley line WI2291/ WI2269//ER/Apm.

Oilseed crops (rapeseed and safflower) were tested by DARI research staff at several sites including Kermanshah, Sanandaj, Maragheh, Ilam, Gonbad, and Gachsaran. In general, rapeseed performs better in higher rainfall (≥400 mm), mild winter areas, with yields of up to 4 t/ha or more under good management. Yield is below 1/ha in mild, dry areas, and about 0.5 t/ha in dry, cold or moderately-cold areas. Therefore, rapeseed cultivation is hindered primarily by lack of moisture, and by cold conditions at germination and establishment. Spring types with high yield identified are primarily the hybrids 'Hayola 401' and 'Hayola 308.' Winter types that did well in Kermanshah in 2003 include the hybrids 'Elite,' 'Ebonite,' and the open-pollinated variety 'Parade,' under rainfed conditions. Under irrigation, the recommended and available varieties for farmers are 'Okapi,' 'Orient,' and 'Cobra.' Safflower was better adapted than rapeseed in harsh, dry areas and has potential of fitting in rotation with barley, in contrast to rape seed which fits in rotation with wheat. Improved varieties of safflower are being evaluated.

Allelopathy experiments in wheat confirmed again the weed-suppressing ability of the genotype 'Batera,' which, in artificially weed-infested fields at Maragheh caused a reduction in the number and dry weight of weeds by 60% and 85%, respectively. Its grain yield (2.5 t/ha) was similar to that of 'Azar 2,' a top yielding cultivar at Maragheh. Other wheat entries showed a lower degree of weed control. Experiments on chickpea and lentil, at Maragheh and Ardebil, showed that residues of some crops mixed with the soil hinder the development of weeds in field conditions. Sunflower residue seemed able to control weeds to an appreciable extent in both chickpea and lentil.

Studies were continued on Sunn pest control in the hot spots in Esfahan province.

Two documents summarizing agronomic research (soil fertility, tillage, etc.) and supplementary irrigation experiments conducted by DARI during the past several years reached completion, and will be published in 2004.

Workshops and coordination meetings

The "Seventh International Conference on Development of Dry Lands" was held in Tehran, Iran in September. More than 200 scientists from 25 countries and international organizations including FAO, ICRISAT, ICARDA, and UNEP, participated in the conference, organized under the auspices of the International Dry Lands Development Commission (IDDC). It was cosponsored by ICARDA and the Ministry of Jihad-e-Agriculture of the Islamic Republic of Iran. Scientific contributions included 100 oral presentations and 80 posters covering diverse topics related to soil and water conservation, forage and range management, biodiversity conservation and utilization, stress physiology, biotechnology, development and transfer of new technologies for dry lands, and the use of indigenous knowledge and heritage.

Intellectual Property Rights (IPR) and genetic resources were the focus of a national seminar organized by ICARDA in collaboration with the Plant Variety Registration Control and Certification Institute (PVRCCI) and the International Union for the Protection of New Varieties of Plants (UPOV). The seminar, held at Karaj, was attended by about 100 policy makers, directors and technical staff of various agricultural centers and institutes in Iran, as well as experts from UPOV and ICARDA. Participants reviewed the global mechanisms of plant variety protection and made recommendations to PVRCCI.

The eleventh IRAN/ICARDA annual planning and coordination meeting took place at Maragheh on 6-11 September, with the participation of more than 50 Iranian and 7 ICARDA scientists. Collaborative work with DARI was reviewed, including the research experiments on breeding wheat, barley, chickpea, lentil, and forage crops; soil and water resource management; and diseases control. A day was devoted to a discussion at AREO-Tehran among a number of scientists from ICARDA, the Seed and Plant Improvement Institute (SPII), and the Plant Pests and Diseases Research Institute (PPDRI) on (i) breeding of wheat, barley, and faba bean with SPII, and (ii) IPM of wheat and barley diseases and insect pests with PPDRI, with particular emphasis on Sunn pest, root diseases, and nematodes.

A stakeholders meeting was held at Karaj by NARS of Iran in collaboration with ICARDA, IRRI and IWMI for developing plans for Kerkhah River Basin research project under 'Water & Food' Challenge Program. The participants also toured the Basin area. Based on these, concept notes were developed and submitted for support, of which two were accepted for funding under the above Challenge Program.

Two researchers from PPDRI were sponsored to participate in the workshop on "IPM for *Orobanche* in Food Legumes Systems in the Near East and North Africa," held in Rabat, Morocco, in April. The scientists presented the Iranian experience in *Orobanche* control. Also, five Iranian scientists involved in the ICARDA-coordinated Sunn pest project participated in a "Sunn Pest IPM Workshop" held in Adana, Turkey in September. As an outcome of the workshop, participants prepared workplans for future research. Other participants came from Syria, Turkey, USA, UK, and ICARDA. Following the meeting, Iranian and ICARDA scientists visited research sites in Esfahan to observe experiments conducted on entomopathogenic fungi. A follow-up two-week training visit was made to ICARDA's entomology laboratory by six Iranian scientists in December.

Human resource development

A training workshop on "Monitoring and Assessing the Adoption and Impact of Improved Production Technology in the Rainfed Areas of Iran" was jointly organized by the Department of Extension and Farming System (DEFS), DARI, and ICARDA in October at Tabriz. Twenty-one participants from Iran and three from ICARDA attended the workshop. Participants discussed concepts and methods of monitoring and evaluating the adoption and impact of improved technology, and reviewed data from a survey conducted by Iranian DEFS staff during 2003.

Five researchers from DARI received specialized short-term training on wheat and barley improvement, chickpea breeding, and farm machinery. Two researchers from SPII participated in a six-week training on barley improvement. Other researchers participated in short courses on: water resources management, scientific writing, soil-borne cereal diseases, and wheat expert systems.

An in-country course was held at Maragheh in February on "Cropping System Models for Extrapolation of the Site-Specific Research Results." Fifteen scientists from DARI and one from ICARDA participated in the course.

From left, **H.E. Prof. Dr Sami Guclu, Minister of Agriculture and Rural Affairs, Turkey, makes a point in discussions with ICARDA Director General Prof. Dr Adel El-Beltagy and Dr Masa Iwanaga, Director General of the International Maize and Wheat Improvement Center, on 5 February 2003, in Ankara, Turkey.**

Turkey

ICARDA's partnership with the Southeastern Anatolia Project Regional Development Administration (GAP-RDA) continued to support improvement in productivity in nine provinces of Turkey. The two components of the project are (i) on-farm demonstration/testing and seed production, and (ii) improvement of natural pastures and forage crops, and small ruminant production. Improved cultivars of wheat, barley and chickpea in demonstration fields yielded notably higher as crop yields of local cultivars on fields compared to out-of-demonstration. ICARDA provided 300 fodder shrub seedlings of 30 species for planting in Haran University, seeds of eight Atriplex species, and new forage legumes were tested.

The annual GAP- RDA/ICARDA technical coordination meeting was held at ICARDA headquarters in March. Achievements of the previous season were reviewed and a workplan for the next season was developed. The meeting noted the considerable progress made in crop improvement, and rangeland/ livestock and seed production. Future plans for GAP-RDA ICARDA collaboration were also discussed.

Twenty-four progressive farmers from GAP-RDA areas visited ICARDA. The farmers viewed crops, seed, and livestock production activities in Syria and ICARDA. Seventeen Turkish scientists from GAP and the Ministry of Agriculture visited ICARDA to participate in courses on seed production, Sunn pest, scientific writing and data presentation, use of taxonomic keys of forage legumes, DNA molecular marker techniques for crop improvement, and water management.

Two training courses were conducted in Turkey; one on "Straw Ammoniation and Feed-Blocks," in which 27 farmers and 12 technical GAP staff participated, and the second on "Soil-Borne Pathogens of Cereals," which attracted scientists from the CWANA region.

Collaboration was continued within Turkey, CIMMYT/ICARDA International Winter Wheat Improvement Project. The ICARDA and CIMMYT Directors General visited the Minister of Agriculture and Rural Affairs of Turkey in February 2003 to discuss on-going cooperation and explore opportunities for new initiatives.

Central Asia and the Caucasus Regional Program

The Central Asia and the Caucasus Regional Program (CACRP), based in Tashkent, Uzbekistan, promotes regional cooperation in research,

H.E. Prof. N. Yusoupov (*third from right*, *front row*), Minister of Agriculture, Uzbekistan, met with the ICARDA Board of Trustees and senior management during their visit to Tashkent, and discussed issues of mutual interest.

capacity building, and human resource development in Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan in Central Asia; and Armenia, Azerbaijan and Georgia in the Caucasus. The program has built strong partnerships with the CAC NARS in germplasm improvement, plant genetic resources, soil and water management, and integrated feed and livestock production.

Collaborative projects

Collaborative research made considerable progress in 2003. 'Dostlik,' a variety of winter wheat from Turkey/CIMMYT/ICARDA nursery, was released in Uzbekistan. In addition, more than 40 promising varieties of wheat, barley, chickpea and lentil were under testing by the State Varietal Testing Commissions for future release. In all, 4650 new accessions/ breeding lines of different crops were supplied to the national programs during the year.

Two germplasm collection missions were conducted (see Project 3.3) in Tajikistan and Armenia in July-August in collaboration with the Ministry of Agriculture of Armenia, the Tajik Academy of Agricultural Sciences and the Vavilov Research Institute (VIR).

Besides the establishment of plant genetic resources (PGR) groups in each of the eight countries of CAC, ICARDA provided technical backstopping and equipment for the setting up of genetic resource centers in Georgia, Uzbekistan, Tajikstan, and Kyrgyzstan.

An agreement for research collaboration was signed between ICARDA and the Republic of Turkmenistan. Two other agreements were signed with Kazakh Agrarian University, Almaty and the Kyrgyz Agrarian University, Bishkek. In June, a strategic partnership agreement for the Global Mechanism (GM) initiatives in the Central Asian countries was signed by the GM and ICARDA in Tashkent. As a starting point in the collaboration, the CACRP Office in Tashkent is now hosting a regional management environmental consultant, who coordinates the GM's work in Central Asia and facilitates the effective implementation of the UNCCD in the region.

The progress in ADB-funded regional project on soil and water management was reviewed in a meeting of national coordinators from five participating countries in which the Project Economist of the East and Central Asia Division of the ADB participated. Proposal for a second phase of the project was discussed.

Workshops and coordination meetings

ICARDA cosponsored an international workshop on "Challenges for Drylands in the New Millennium: A Cross-Cutting Approach for Assessment" in Tashkent, Uzbekistan in August. The other cosponsors were the United Nations University (UNU) and the Millennium Ecosystem Assessment (MA). Over 30 experts in dryland management representing 15 countries participated in the workshop. They reviewed the ongoing efforts for sustainable development of drylands, the role of dryland ecosystem goods and services in promoting such development, and desertification as an impediment to the provision of ecosystem goods and services.

The "First Central Asian Wheat Conference," was held in Almaty, Kazakhstan, cosponsored by Kazak NARS, CIMMYT, ICARDA, and donors. It was aimed at assessing the status of research and cooperation on wheat improvement in Central Asia, particularly, in the field of wheat breeding, genetics, plant protection, biotechnology and agronomy; evaluating the achievements of the regional cooperation on wheat varieties' promotion and seed production; and facilitating information exchange between scholars and specialists from Central Asia and other countries. Over 200 scientists participated.

The fourth steering committee of the IFAD-Funded project was held at Tashkent, and was attended by project scientists and donor representatives. The NARS presented the results of their activities and future plan of the project. A regional conference on "Policies and Technology Options for Livestock Development in Central Asia and the Caucasus" was held in Tashkent to review research activities undertaken during the first phase of the IFAD funded project. Thirty scientists from Ministries of Agriculture from CAC countries, NARS and ICARDA, as well as representatives from IFAD, the World Bank, and the European Union, participated in the conference.

The seventh ICARDA-CAC regional coordination meeting was held in Yerevan, Armenia in

Participants of the Seventh ICARDA-CAC Regional Coordination Meeting, held in Yerevan, Armenia, 26-28 September 2003.

H.E. Prof. A. Juraev (center, front row), Minister of Agriculture and Water Management, Uzbekistan with the participants of the Regional Conference on Policies and Technology Options for Livestock Development in Central Asia and the Caucasus, held in Tashkent, 2-5 October, 2003.

September. Forty-five participants, including the heads of the seven NARS from the CAC region, ICARDA scientists, representatives of other international and donor organizations as well as NGOs, attended the meetings. Discussions focused on germplasm enhancement and natural resources management. Two separate special sessions were held on developing project proposals on mountain agriculture and livestock and range biodiversity.

In order to review the progress made by the CAC-PGR working groups in collection, documentation, characterization and conservation of plant genetic resources, a regional meeting was held in Tashkent, Uzbekistan, in December. Twenty-eight participants from all the eight countries of the region and ICARDA participated in the meeting.

Members of ICARDA Board of Trustees visit the research site at the Tashkent State Agrarian University in Uzbekistan.

A joint FAO-ICARDA mission visited Kazakhstan, Tajikistan, and Uzbekistan from 21 January to 16 February to assess the efficiency of seed supply, distribution, and marketing systems. The team met with senior officials of the ministries of agriculture, representatives of public and private seed sectors, NGOs and donors. They proposed an action plan to address key issues including reformation of the governmental seed sector support programs, improvement of local seed production systems, and development of regionally competitive seed industries with effective links to the international seed industries. The mission was followed by a special meeting on seed harmonization in the CAC region held in September in Armenia. Participants agreed that in order to harmonize issues of seed production, marketing, and quality control, the NARS of the region should be assisted to organize a regional seed network.

Senior agricultural research managers from Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan attended a Workshop on "Rural Development Strategy in CWANA," organized by ICARDA in Cairo, Egypt. The workshop focused on the World Bank's new strategy on rural development.

Human resource development

Strengthening the capacity of the NARS in the region continues to be a priority of ICARDA. A total of 460 CAC scientists and farmers participated in different international conferences, workshops, seminars, field visits and training courses. In addition, 35 scientists from all CAC countries participated in an intensive training course in English held in Tashkent.

CACRP, in partnership with the International Center for Biosaline Agriculture (ICBA), organized a training course on "Biosaline Agriculture and Sustainable Production Systems," in Tashkent. Twenty-seven participants from five Central Asian countries and Azerbaijan attended the training which addressed issues of soil salinity and water management.

Scientists from Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan participated in the second traveling workshop on food legumes in Central Asia. The objectives of the workshop were to evaluate and select improved lentil and chickpea lines, and discuss problems and a future plan of action for legume improvement. The group jointly visited Andijan and Galla-aral research stations in Uzbekistan and Krasny Vodopad station in Kazakhstan.

CACRP supported the participation of six scientists from the CAC region in the seventh International Conference on Development "of Dry Lands," held in Tehran, Iran. The Conference provided on opportunity to exchange research results and experience in dryland development and control of desertification.

Communication, Documentation and Information Services

The Communication, Documentation and Information Services (CODIS) Unit continued to provide a variety of services to scientists at headquarters, in regional programs, and in NARS.

The year saw the launch of the Arabic version of ICARDA's website (www.icarda.org/Arabic/IndexAr.htm). The website continued to be enriched with Arabic publications including the Center's Annual Reports and other information material. In addition, CODIS made design improvements on the English version of the Center's website, enriching the content and adding new links. Both the English and Arabic sites attracted a large number of visitors from all over the world.

A website on medicinal and aromatic plants was developed within the context of the "Medicinal and Aromatic Plants (PAM)" project in southern Tunisia, implemented by the *Institut des Regions Arides* (IRA), Tunisia, in collaboration with the United States Department of Agriculture (USDA-ARS) and ICARDA. Also, web pages were developed on Moroccan Collaborative Research Grants, in response to a request from the Moroccan national program.

Within the framework of the Marketing Group of the CGIAR, CODIS led the development of a proposal to produce a comprehensive report on the role of the CGIAR centers in "Rebuilding Agriculture in Countries Affected by Conflicts and Natural Disasters." The proposal was approved and contributions from the participating centers were received to develop a monograph on the subject. The monograph is expected to be published in 2004.

Agriculture Minister of Afghanistan, H.E. Mr Sayed Hussain Anwari (*right*), is interviewed by Mr Enayat Safi in the Ministry's refurbished studio. Mr Safi produces a weekly radio program for farmers, funded by the ICARDA-led Future Harvest Consortium.

Several communication activities related to rebuilding agriculture in Afghanistan were conducted by CODIS during 2003. Within the framework of activities of the "Future Harvest Consortium to Rebuild Agriculture in Afghanistan," supported by USAID, a new audio editing and recording studio was installed at the Ministry of Agriculture and Livestock in Kabul, and was officially launched by the H.E. Sayed Hussain Anwari, Afghanistan's Minister of Agriculture and Livestock. Afghanistan pages on ICARDA's website were redesigned and enriched with research reports on livestock, rangelands and feed. Many news releases were issued to provide updates on the progress of work in Afghanistan.

ICARDA's Virtual Library continued to serve the NARS by providing them with access to millions of records through the Center's website. The ICARDA Library, which has a rich collection of scientific publications, acquired 180 new books and over 1000 journals and annual reports during the year.

CODIS continued to offer capacity building support to NARS in the CWANA region. Two training courses were held, one on "Electronic Documents and Bibliographic Database Management on the Web," which attracted 17 participants from five countries; and another on "Scientific Writing," which attracted 11 participants from 10 countries. In addition, NARS staff from Sudan, Ethiopia, and Tunisia came to CODIS for individual training in various fields including information management, website development, and multimedia productions.

Many books and information materials were developed during the year including an issue of ICARDA Caravan, devoted to rebuilding agriculture. ICARDA publications were distributed and displayed at major meetings and events including the Annual General Meeting of the CGIAR in Nairobi, Kenya and at the Global Forum on Agricultural Research meeting, held in Dakar, Senegal. At the GFAR meeting, an ICARDA poster on "Linking Research and Rural Innovation to Sustainable Development" designed by CODIS, won an award.

Computer and Biometric Services Unit

The Computer and Biometric Services Unit (CBSU) enhanced the Internet bandwidth and installed alternative connections including satellite and land-based links. The site design for the ICARDA Intranet was improved. Information on ICARDA, the CRISP database and an English-Arabic dictionary of statistical terms was uploaded to the

Intranet. The local area Fast-Ethernet computer network was extended to the Sheep Unit. Migration to Windows 2003 Server and Windows XP operating systems was initiated. The Unit continued to support ICARDA's outreach offices including the Kabul office. Hardware maintenance, local area network, and Internet access were provided to the ICARDA School.

In cooperation with NRMP, the Unit developed a new Meteorological Database using Oracle DBMS. The Unit also created a "Professionals for Iraq Reconstruction Registry" website and an "Economic Assessment of On-Farm Water Use Efficiency in Agriculture" for ESCWA.

For the Oracle Financial/ Administrative Applications, 15 new custom reports and 2 forms were developed, 57 custom reports and several procedures were modified. The payroll system was re-designed to upgrade it to release 11i, and 22 forms and 15 reports and 5 programs were developed. Offers for the implementation of Oracle Applications 11i and project quality assurance from consultants were solicited and analyzed.

Biometric consultancies were rendered to researchers on 110 occasions. Statistical software and data management support was provided on 80 occasions and online computing on 95 sessions of data analyses. Statistical designs were developed for many experiments including those on crop-loss assessment in cereals; fungicide application on chickpea; supplemental irrigation on two summer crops; diversity studies on wild and cultivated lentils and peas; restoration of species of legumes and grasses for the steppes in Syria; and seed-storage factors on seed germination.

Statistical analysis services continued to be provided to headquarters scientists in a variety of ongoing experiments and trials. The Unit provided biometric support to NARS on analysis of wheat yields under supplemental irrigation in Central Anatolia, Turkey and estimations of genotypic and phenotypic correlations. A procedure for estimating heritability in lentil trials exhibiting spatial variability in the presence of G x E interaction was developed. CBSU also developed a program for pair-wise group means comparisons from spatial analysis of field trials. A statistical methodology has been formulated to measure consistency (repeatability) of genotype x location interaction over time, using bootstrap re-sampling of locations.

The Unit developed a joint project proposal on "Utilization of Intelligent Information Systems for Crop Protection" which was submitted to the CGIAR Chief Information Officer. A project proposal for establishing a website for TPN4 was submitted to the UNCCD.

CBSU contributed to various training courses in ICARDA on "Application of Molecular Tools for Bio-diversity Studies," "Management of Water Resources and Improvement of Water-Use Efficiency in the Dry Areas," and "Scientific Writing and Data Presentation." The Unit also trained several scientists from NARS and provided in-house training on various software packages.

Human Resource Development Unit

During 2003, ICARDA offered training opportunities to 538 national scientists from 31 countries including CWANA, Africa, Asia and the Pacific region, and Europe. Fifty-one national scientists from both developing and industrialized countries conducted research for MSc and PhD degrees jointly between ICARDA and agricultural universities around the world. About 20% of ICARDA training participants were women.

ICARDA continued its strategy to gradually decentralize its training activities by offering more non-headquarter training courses. During the year, ICARDA offered 15 headquarters training courses and 16 in-country, regional and sub-regional courses.

In its efforts to respond to the demands for training from NARS, the Human Resources Development Unit (HRDU) also facilitated and coordinated the implementation of several training courses for external-funded projects. Examples include:

1. In-country training course on "Planning and Management of Water Resources," funded by the Syrian Ministry of Irrigation and UNDP.
2. Regional training workshop on "Participatory Research Methods and Community Approach and Characterization," held in Cairo, Egypt, sponsored by IFAD.
3. Regional training course on "Management of Water Resources and Improvement of Water-use Efficiency in the Dry Areas." This was the Center's second year to conduct this ICARDA/JICA joint training course and 28 senior researchers from 16 different countries participated. Several participants in this course were sponsored by the International Center for Biosaline Agriculture (ICBA), based in Dubai, Emirates, and the Danish Committee for Aid to Afghan Refugees (DACAAR) operating in Afghanistan.
4. Regional training course on "Biosaline Agricultural and

Sustainable Production Systems," jointly organized and sponsored by ICBA and ICARDA, held in Tashkent, Uzbekistan.
5. Training course on "Seed Processing and Storage," jointly funded by the Southern Anatolia Development Project in Turkey.
6. Training Workshop on "Intellectual and Tangible Property Management in Agriculture." This advanced training workshop involved 11 NARS leaders and policy makers from Algeria, Iran, Iraq, Jordan, Lebanon, Sudan, Syria, Tunisia as well as 11 senior scientists and management members from ICARDA. The workshop instructors were Dr John Dodds (ICARDA legal counsel) and Dr Anatole F. Krattiger from the College of Agriculture and Life Sciences, Cornell University, USA and it was partially funded by SYNGENTA.
7. In-country training course on "Cereal Diseases and Integrated Disease Management," held in Halhale, Asmara. The course was organized by ICARDA (ICDM-project and NVRSP) and the Department of Agricultural Research and Human Resources Development (DARHRD), Ministry of Agriculture in Eritrea, and was funded by the Danish International Development Assistance (DANIDA).
8. Regional training course on "Utilization of Expert Systems in Agricultural Research and Production," held at the Central Laboratory for Agricultural Expert Systems (CLAES) in Cairo, Egypt.

A training course on DNA Molecular Marker Techniques in progress in ICARDA biotechnology laboratory.

9. Regional training workshop on "Quality Assurance in Seed Testing," held in Cairo, Egypt, organized and sponsored by FAO, GTZ, CASC, ISTA and ICARDA.
10. Regional training course "Electronic Document Management and the Use of WebAGRIS Tools for Database Management on the Web," jointly organized and sponsored by ICARDA/FAO-RNE in Cairo, Egypt and the Arab Organization for Agricultural Development (AOAD).
11. Eight different training courses were organized for participants from Afghanistan in different subjects including Integrated Pest Management of Sunn Pest; Weather Station Installation and Use; Seed Health Testing; Quality Assurance in Seed Testing; Seed Production Technology and Enterprise Management and Experimental Station Operation Management. The courses were organized through the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), led by ICARDA, and the Ministry of Agriculture and Livestock in Afghanistan, and sponsored by the United States Agency for International Development (USAID). The IPM course was jointly organized with Vermont University, USA.
12. Three courses on "DNA Molecular Marker Techniques for Crop Improvement" were organized at ICARDA headquarters as regional training course, for the University of Khartoum, Sudan, and the University of Tishreen in Lattakia, Syria.
13. "Dryland Management and Combating Desertification," funded by the Syrian Ministry of Local Administration and Environment through UNDP.

Inter-Center collaboration was also strengthened through participation in the Inter-Center Training Group (ICTG). Efforts were made to further improve the ICARDA training database and place it on the Center's Intranet. A new home page for HRDU was also developed and placed on ICARDA's Web page.

Appendices

Appendix 1

The following list covers journal articles published in 2003 by ICARDA researchers, many of them in collaboration with colleagues from national programs. A complete list of publications, including book chapters and papers published in conference proceedings, is available on ICARDA's web site: www.icarda.cgiar.org.

Journal Articles

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Zaid, N., O. Kafawin, H. Halila, and H. Saoub. 2003. Genotype by environmental interaction, growth rate and correlation for some lentil *(Lens culinaris)* genotypes grown under arid conditions in Jordan. Dirasat, Agricultural Sciences 30(3): 374-383.

Appendix 2

Graduate Theses Produced with ICARDA's Joint Supervision

Master of Science

Norway, Norway Agricultural University

Costantinos, Biniam. 2003. Developing methodology to assess gully processes using AV GIS in dryland Khanasser Valley, Syria. 66 pp.

Jordan, University of Jordan

Teferra, Beneberu. 2003. Sheep price patterns and factors affecting price variations in highland markets of north Shewa, Ethiopia. 99 pp. (In English, Arabic summary).

Syria, University of Aleppo

Amaraya, Shahla. 2003. Toward an integrated management of wilt/root rot complex in lentil under Syrian conditions. 130 pp. (In Arabic, English summary).

Hammadeh, Ibrahim. 2003. Determination of the best techniques to study the tolerance of chickpea (*Cicer arietinum* L.) to drought and frost. 177 pp. (In Arabic, English summary).

The Netherlands, Vrije Universiteit

Luijendijk, Elco. 2003. Groundwater resources of the Aleppo basin, Syria. 99 pp.

Doctor of Philosophy

Belgium, Katholieke Universiteit

Cools, Nathalie. 2003. Multi-scale participatory land resource assessment in northwest Syria. 345 pp.

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Dinssa, F.F. 2003. Molecular genetic variation, yield and yield components of barley (*Hordeum vulgare* L.) in decentralized-participatory breeding in low moisture environments. 204 pp.

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Rida, Fadel. 2003. Computer simulation models for sustainable groundwater in agriculture in Syria. 180 pp.

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Agreements Signed in 2003

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27 May 2003. Memorandum of Understanding between the United Nations Economic and Social Commission for Western Asia (ESCWA) and ICARDA.

7 July 2003. Memorandum of Understanding between ICARDA and Japan International Research Center for Agricultural Sciences (JIRCAS).

24 September 2003. Agreement between the Ministry of Agriculture of Turkmenistan and ICARDA on cooperation in the field of agricultural science.

Appendix 4

Restricted Projects

ICARDA's research program is implemented through 19 research 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 2003, the following Restricted 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).
- Sustainable management of natural resources and improvement of major production systems of the Arabian Peninsula.
- Options for coping with increased water scarcity in agriculture in West Asia and North Africa

Asian Development Bank

- On-farm soil and water management for sustainable agricultural systems 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.
- Conservation, evaluation and utilization of plant genetic resources from Central Asia and the Caucasus.
- Host resistance, epidemiology and integrated management of faba bean, chickpea and lentil diseases.

Cooperative Research Center for Molecular Plant Breeding

- Collaborative barley breeding for low rainfall environments

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Cooperative Research Center for Molecular Plant Breeding

- Collaborative barley breeding for low rainfall environments

GRDC (Grains Research and Development Corporation)

- Preservation and utilization of the unique pulse and cereal genetic resources of the Vavilov Institute.
- 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).
- Improvement of drought tolerance in lentils
- Coordinated improvement of chickpeas in Australia – Northern Region module.
- Faba Bean Improvement - Northern Region.
- Associate Expert in legume pathology.
- International Durum Wheat Improvement Cooperation

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

Canada

CGIAR-Canada Linkage Funds

- The increasing role of women in resource management and household livelihood strategies.

Crop Development Centre, University of Saskatchewan

- Off-season evaluation of ascochyta blight reaction in chickpea

CGIAR Impact Assessment and Evaluation Group (IAEG) / Standing Panel on Impact Assessment (SPIA)

- CGIAR's impact on germplasm improvement.
- Ex-post impact assessment of natural resources management technologies in crop-livestock systems in arid and semi arid areas

CGIAR Challenge Programs

Harvest Plus

- 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

CGIAR Systemwide Programs

CGIAR Collaborative Program for Central Asia and the Caucasus

- Program Facilitation Unit.
- Germplasm conservation, adaptation and enhancement.
- On-farm soil and water management

Systemwide Genetic Resources Program (SGRP)

- Management and characterization of small ruminants.
- Global inventory of barley genetic resources.

Systemwide Program on Integrated Pest Management

- Inter-Center IPM Adoption Initiative: Pilot sites in Egypt and Morocco.
- SP-IPM Soil Biota Global Workshop.

Systemwide Livestock Program (SLP)

- Production and Utilization of Multi-Purpose Fodder Shrubs and Trees in West Asia, North Africa and the Sahel
- Characterization of livestock genetic resources in the Caucasus region

Systemwide Programme for Participatory Research and Gender Analysis (SP-PRGA)

- Analysis of participatory research and gender analysis approaches in ICARDA.

Systemwide Program on Soil Water and Nutrient Management (SWNM)

- Optimizing soil water use.

CIHEAM (International Centre for Advanced Mediterranean Agronomic Studies)

- Mediterranean Rainfed Agriculture Technologies Evaluation (MEDRATE): Evaluation of agricultural practices to improve efficiency and environment conservation in Mediterranean arid and semi-arid production systems.
- Screening legumes and forage nursery for salinity tolerance.

Denmark

- Integrated disease management to enhance barley and wheat production in Eritrea.

- Junior Professional Officer in milk transformation.
- Junior Professional Officer in characterization of small ruminant production and associated local knowledge systems.

EC (European Commission)

EC Attributed Funding

- Durum wheat germplasm improvement for increased productivity, yield stability and grain quality.
- Food legume germplasm improvement (lentil, kabuli chickpea, faba bean and pea) for increased systems productivity.
- Agrobiodiversity collection and conservation for sustainable production.

EC 6th Framework INCO

- Mapping Adaptation of Barley to Drought Environments (MABDE)
- Improving durum wheat for water use-efficiency and yield stability through physiological and molecular approaches (IDuWUE)

ERF (Economic Research Forum) FEMISE Program

- Les obstacles aux transferts technologiques dans les petites et moyennes exploitations agricoles des zones arides et semi arides du Maghreb. Discussion sur les conditions d'amélioration de la productivité en Algérie, Maroc et Tunisie.

ESCWA (UN Economic and Social Commission for West Asia)

- Database design concerning the establishment of a Professionals Registry for Iraq Reconstruction
- Development of user-friendly interface with models used in analysis of on-farm water use efficiency

FAO (Food and Agriculture Organization of the United Nations)

- Translation of AGROVOC terms into Arabic.
- Sub-Regional training course on electronic document management and the use of WebAgris tools for database management and development
- Expert Consultation on IPM for *Orobanche* control in food legume systems in the Near East and North Africa.
- Preparation of a book on local knowledge on food barley
- Oat-Vetch Regional Network (REMAV) Meeting
- Seventh International Conference on Dry Lands
- Translation into Russian and publication of the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture.
- Applied Research to improve and maintain Seed Quality for Fodder Shrubs and Grass Species used for Rangeland Rehabilitation
- Regional Workshop on Seed Quality Assurance in Seed Testing

France

- Associate Expert in socioeconomics of rangeland management.

GEF (Global Environment Facility) / UNDP (United Nations Development Programme)

- Conservation and sustainable use of dryland agrobiodiversity in Jordan, Lebanon, Syria and the Palestinian Authority.

Germany

- An integrated approach to sustainable land management in dry areas.
- Functional genomics of drought and cold tolerance in chickpea and lentil.
- Exploration of genetic resources collections at ICARDA for adaptation to climate change

IDRC (International Development Research Centre)

- From formal to participatory plant breeding: improving barley production in the rainfed areas of Jordan.
- Scaling up decentralized participatory plant breeding in Syria
- Improving natural resources management and food security for rural households in the mountains of Yemen.
- Strengthening seed systems for food security in Afghanistan.

IFAD (International Fund for Agricultural Development)

- Sustainable management of natural resources and improvement of major production systems of the Arabian Peninsula.
- Integrated feed and livestock production in the steppes of Central Asia.
- Assistance in developing policies and strategies to improve livestock production systems in Central Asia and the Caucasus

- Program for Strengthening Research and Development to Improve Marketing of Small Ruminant Products and Income Generation in Dry Areas of Latin America
- Agro-pastoral Development and Local Initiatives Promotion Program in the South-East (PRODESUD)
- Program to foster wider adoption of low-cost durum technologies.
- Program for enhancing food security in the Nile Valley and Red Sea region: Technology generation and dissemination for sustainable production of cereals and cool-season food legumes.
- Technical assistance for accelerated project performance in North Africa.

International Nutrition Foundation

- Impact of lysine fortified wheat flour on the nutritional status of rural families in northwest Syria.

Iran

- Scientific and technical cooperation and training.

Italy

Italy Attributed Funding

- Durum wheat germplasm improvement for increased productivity, yield stability and grain quality in West Asia and North Africa.
- Barley germplasm improvement for increased productivity.
- Food legume germplasm improvement for increased systems productivity: Chickpea improvement.

Japan

- Improving income of small-scale producers in marginal agricultural environments: small ruminant milk production and milk derivatives, market opportunities and improving value added returns.
- Training program in management of water resources and improvement of water-use efficiency in dry areas

Japan Attributed Funding

- Rehabilitation and improved management of native pastures and rangelands in dry areas.
- Improvement of small ruminant production in dry areas.
- Germplasm enhancement for diversification and intensification of agricultural production in Central Asia and the Caucasus.

Korea: Rural Development Administration (RDA), Republic of Korea

- Barley research

Morocco

- Collaborative activities in crop improvement, biotechnology, GIS and agroecological information system services, genetic resources and biodiversity, and integrated management of cereal and legume pests

OPEC Fund for International Development

- Decentralization of barley breeding with farmers' participation.
- Sustainable management of natural resources and improvement of major production systems of the Arabian Peninsula.
- Community-based research for agricultural development and sustainable resource management in Afghanistan

Pakistan

- Cooperation in the applied research component of the *Barani* Village Development Project (BVDP).

Switzerland

Swiss Agency for Development and Cooperation

- Sustainable management of the agropastoral resource base in the Maghreb.
- Associate Expert

Swiss Centre for International Agriculture (ZIL), Federal Institute of Technology Zurich (ETHZ)

- Research Fellowship project on improving resistance to barley scald

Turkey

- Technical assistance to Southeast Anatolia Project Regional Development Administration.

United Kingdom

DFID (Department for International Development) Competitive Research Facility

- Improving the yield potential and quality of grasspea (*Lathyrus sativus* L.): a dependable source of dietary protein for subsistence farmers in Ethiopia.
- Integrated pest management of Sunn pest in West Asia.

British Embassy, Damascus

- Restoring production and ecological integrity to high-potential low-lying areas in the Syrian steppe.

U.K. Attributed Funding

- Food legume germplasm improvement for increased systems productivity.
- Land management and soil conservation to sustain the agricultural productive capacity of dry areas.
- Socioeconomics of agricultural production systems in dry areas.

UNCCD (United Nations Convention to Combat Desertification) Global Mechanism

- Regional Environmental Management Officer, Tashkent.
- Establishment of a website for TPN4

Global Mechanism of the UNCCD

- Development of a facilitation unit for the establishment of a Regional Program for Sustainable Development of the Drylands of West Asia and North Africa
- Regional Program for Sustainable Development of the Drylands of West Asia and North Africa: Inventory of activities and gap analysis

UNCCD Sub-Regional Action Program (SRAP) for West Asia

- Inventory study and regional database on sustainable water management in West Asia
- Preparing project proposals on integrated natural resources management for combating desertification in West Asia
- Integrated natural resources management programme to combat desertification in Lebanon and Jordan (Pilot Projects)

United States of America

USAID (United States Agency for International Development)

- Assisting Afghan farmers to restore food security.

USAID Linkage Funds

- Adaptation of barley to drought and temperature stress using molecular markers.
- Inheritance and mapping of winter hardiness genes in lentil for use in marker assisted selection.
- Use of entomopathogenic fungi for the control of Sunn pest in West Asia.
- Poverty, agricultural household food systems and nutritional well-being of the child.
- Improving water-use efficiency with a web-based information system
- Evaluation of pulse genetic resources

USAID Rebuilding Agricultural Markets Program (RAMP), Afghanistan

- Village Seed Enterprise Program
- 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

USDA/ARS (United States Department of Agriculture/Agricultural Research Service)

- Collection of plant genetic resources in the Central Asian and Caucasus region.
- Climatological analysis as a tool for agricultural decision making in dry areas
- Biotechnology assessment for North Africa
- Identifying wheat and barley germplasm resistant to Syrian and United States populations of the Russian Wheat Aphid

USDA/FAS (United States Department of Agriculture/Foreign Agricultural Service)

- Biological diversity, cultural and economic value of medicinal, herbal and aromatic plants in southern Tunisia.
- Partnership to improve rural livelihoods in West Asia and North Africa through strengthened teaching and research on sheep and goat production.
- GIS for watershed management in the arid regions of Tunisia.
- Research on improving productivity of oats as a priority forage species in Tunisia.
- Biological control of weeds with plant pathogens

World Bank

- Workshop on Rural Development in WANA
- Regional initiative for dry land management

Appendix 5

Collaboration with Advanced Research Institutes and Regional and International Organizations

CGIAR Centers and Regional/International Organizations

ACSAD (The Arab Center for the Studies of Arid Zones and Dry Lands)

- Joint workshops, conferences and training.
- Exchange of germplasm.
- Cooperation in Thematic Networks (TN1 and TN2) of the UN Convention to Combat Desertification (UNCCD) Sub-Regional Action Program for Western Asia.
- Cooperation in GEF/UNDP project on "Conservation and sustainable use of dryland agro-biodiversity in Jordan, Lebanon, Palestinian Authority and Syria".

AOAD (Arab Organization for Agricultural Development)

- Sub-regional training course on electronic document management and tools for database management and development.

CIAT (Centro Internacional de Agricultura Tropical)

- ICARDA participates in the Systemwide Program on Soil Water and Nutrient Management (SWNM) and in the Systemwide Program on Participatory Research and Gender Analysis (PRGA), both coordinated by CIAT.
- ICARDA is participating in the Challenge Program on Biofortified Crops for Improved Human Nutrition (HarvestPlus), led by CIAT and IFPRI.

CIHEAM (International Center for Advanced Mediterranean Agronomic Studies)

- Joint training courses and information exchange.
- Study of the tolerance of ICARDA mandate crops to salinity at CIHEAM Mediterranean Agronomic Institute of Bari.
- ICARDA participates in the FAO-CIHEAM subprogram for nutrition and feeding strategies and the subprogram for breeding strategies for sheep and goats.
- Collaboration with CIHEAM Mediterranean Agronomic Institute of Zaragoza in the evaluation of Mediterranean rainfed agriculture technologies.
- ICARDA participates in the Collaborative Molecular Biotechnology Integrating Network (COMBINE) coordinated by CIHEAM Mediterranean Agronomic Institute of Chania.
- ICARDA participates in the FAO/CIHEAM Cooperative Research Network on Sheep and Goats, Genetic Resources Sub-Network.
- ICARDA is participating in a project on mapping adaptation of barley to drought environments coordinated by CIHEAM.
- CIHEAM, ICARDA and FAO-RNE are co-conveners of the Network on Drought Management for the Near East, Mediterranean and Central Asia (NEMEDCA Drought Network).
- Collaboration in Consultative Workshop on Participatory Plant Breeding.

CIMMYT (International Center for the Improvement of Maize and Wheat)

- CIMMYT/ICARDA cooperate through the Joint Dryland Wheat Program.
- An ICARDA barley breeder is seconded to CIMMYT.
- CIMMYT's outreach program in Turkey and ICARDA's Highland Regional Program share facilities in Ankara, Turkey and collaborate with Turkey in a joint Winter and Facultative Wheat Improvement Program.
- ICARDA and CIMMYT jointly coordinate a durum wheat research network encompassing WANA and southern Europe.
- CIMMYT participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA.
- CIMMYT participates in the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), coordinated by ICARDA.

CIP (International Potato Center)

- CIP participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA.
- CIP participates in the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), coordinated by ICARDA.

ESCWA (UN Economic and Social Commission for West Asia)

- Development of a website for " Professionals for Iraq Reconstruction"

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.
- Joint planning in areas of feeding resources and strategies with FAO's Animal Production and Health Division.
- ICARDA participates in the FAO/CIHEAM Cooperative Research Network on Sheep and Goats, Genetic Resources Sub-Network.
- ICARDA cooperates with the FAO Commission on Plant Genetic Resources.
- ICARDA participates in the Inter-agency Task Forces convened by the FAO-RNE (FAO Regional Office for the Near East).
- FAO-RNE, ICARDA and CIHEAM are co-conveners of a Network on Drought Management for the Near East, Mediterranean and Central Asia (NEMEDCA Drought Network).
- Joint training courses, workshops, publications and exchange of information.
- ICARDA cooperates with FAO in translating FAO plant and animal terminology to Arabic.
- Expert Consultation Meeting on *Orobanche* management in food legumes
- 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

FAO/IAEA (International Atomic Energy Agency) Joint Division

- Management of nutrients and water in rainfed arid and semi-arid areas for increasing crop production.
- Research in feeding systems for small ruminants in the dry areas.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)

- ICRISAT participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA.
- ICRISAT participates in the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), coordinated by ICARDA.
- ICARDA and ICRISAT are co-conveners of the sub-program on Optimizing Soil Water Use within the Systemwide Program on Soil Water and Nutrient Management.
- ICARDA is collaborating with ICRISAT on insect pests of grain legumes within the Systemwide Program on Integrated Pest Management.
- ICARDA and ICRISAT are co-conveners of the Consortium on Desertification, Drought, Poverty, and Agriculture (DDPA).
- ICARDA and ICRISAT collaborate in the Cereal and Legumes Asia Network (CLAN).

IFPRI (International Food Policy Research Institute)

- ICARDA participates in the System Wide Program on Collective Action and Property Rights (CAPRi) coordinated by IFPRI.
- IFPRI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA.
- IFPRI participates in the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), coordinated by ICARDA.
- Collaboration in research on property rights and collective action in CWANA through a joint staff appointment.
- ICARDA is participating in the Agricultural Science and Technology Indicators (ASTI) Initiative led by IFPRI and ISNAR.
- ICARDA is participating in the Challenge Program on Biofortified Crops for Improved Human Nutrition (HarvestPlus), led by IFPRI and CIAT

IITA (International Institute of Tropical Agriculture)

- ICARDA is collaborating with IITA on parasitic weeds within the Systemwide Program on Integrated Pest Management.

ILRI (International Livestock Research Institute)

- ILRI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA.
- ILRI participates in the Future Harvest Consortium to rebuilding Agriculture in Afghanistan (FHCRAA), coordinated by ICARDA.
- ILRI and ICARDA share a joint position on animal epidemiology.
- ILRI and ICARDA cooperate in strengthening teaching and research on sheep and goat production in Tunisia.

IPGRI (International Plant Genetic Resources Institute)

- ICARDA hosts and services the IPGRI Regional Office for Central and West Asia and North Africa (IPGRI-CWANA).
- ICARDA participates with other CG Centers in the

Systemwide Genetic Resources Program, coordinated by IPGRI, in both plant and animal genetic resources.
- IPGRI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA.
- IPGRI participates in the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), coordinated by ICARDA.
- ICARDA collaborates with IPGRI in two subregional networks on genetic resources (WANANET and CATN/PGR).
- ICARDA participates in developments of the SINGER project coordinated by IPGRI and contributes data to the core SINGER database.
- IPGRI-CWANA is a partner with ICARDA in the GEF/UNDP project on "Conservation and sustainable use of dryland agro-biodiversity in Jordan, Lebanon, Palestinian Authority and Syria."

IRRI (International Rice Research Institute)
- IRRI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA.
- IRRI participates in the Future Harvest Consortium for Rebuilding Agriculture in Afghanistan (FHCRAA), coordinated by ICARDA.

ISTA (International Seed Testing Association)
- Joint regional workshop on Quality Assurance in Seed Testing

IWMI (International Water Management Institute)
- IWMI participates in the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, coordinated by ICARDA.
- IWMI participates in the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA), coordinated by ICARDA.
- ICARDA is participating in the Challenge Program on Water and Food, coordinated by IWMI.
- ICARDA serves on the Steering Committee of the Systemwide Initiative on the Comprehensive Assessment of Water, coordinated by IWMI.
- IWMI and ICARDA share a joint position on marginal water use.

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 sustainable land management of marginal drylands

AUSTRALIA

Australian Winter Cereals Collection, Tamworth.
- Development and conservation of plant genetic resources in the Central Asian Republics.
- Bread wheat landrace eco-geographic diversity studies.

Australian Temperate Field Crops Collection, Horsham.
- Development and conservation of plant genetic resources in the Central Asian Republics.
- Host resistance, epidemiology and integrated management of faba bean, chickpea and lentil diseases

University of Adelaide, CRC for Molecular Plant Breeding
- 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

University of Adelaide, Waite Campus
- Host resistance, epidemiology and integrated management of faba bean, chickpea and lentil diseases.

Centre for Management of Arid Environments, Kalgoorlie, WA
- International collaboration in grazing management

Centre for Plant Conservation Genetics, Southern Cross University
- Development of ESTs using wild barley from ICARDA.

CLIMA (Centre for Legumes in Mediterranean Agriculture)
- Development and conservation of plant genetic resources in the Central Asian Republics.
- Preservation of the pulse and cereal genetic resources of the Vavilov Institute.
- Improving crop establishment and yield of relay and post-rice-sown pulses (lentil and *Lathyrus*) in the cropping systems of the terai and mid-hills in Nepal
- Development of interspecific hybrids between chickpea and its wild relatives.
- Host resistance, epidemiology and integrated management of faba bean, chickpea and lentil diseases.

Department of Agriculture, Western Australia
- Host resistance, epidemiology and integrated management of faba bean, chickpea and lentil diseases.

NSW Agriculture, Tamworth Centre for Crop Improvement
- Durum wheat improvement.
- Chickpea improvement.
- Identification of legume viruses and selection of legume germplasm for virus disease resistance.
- Host resistance, epidemiology and integrated management of faba bean, chickpea and lentil diseases.

Plant Breeding Institute, University of Sydney
- Near isogenic lines for the assessment of pathogenic variation in the wheat stripe (yellow) rust pathogen
- Breeding for resistance to barley stripe (yellow) rust.

Victorian Institute for Dryland Agriculture
- Improvement of lentil and grasspea in Bangladesh.
- Improvement of narbon vetch for low rainfall cropping zones in Australia.
- Improving crop establishment and yield of relay and post-rice-sown pulses (lentil and *Lathyrus*) in the cropping systems of the terai and mid-hills in Nepal
- Coordinated improvement project on Australian lentils
- Host resistance, epidemiology and integrated management of faba bean, chickpea and lentil diseases.

AUSTRIA

Federal Institute for Agrobiology, Linz
- Safety duplication of ICARDA's legume germplasm collection

University of Natural Resources and Applied Life Sciences, Vienna
- Production diversification in small ruminant production in some countries of WANA

BELGIUM

University of Gent
- Assessment of *Vicia sativa* and *Lathyrus sativus* for neurotoxin content.

University of Leuven
- MSc thesis on integrated assessment of land degradation assessment.
- Cooperation with the Laboratory of Experimental Geomorphology on strengthening livelihood resilience in upper catchments of dry areas by integrated natural resources management

CANADA

Agriculture Canada, Field Crop Development Centre, Alberta
- Development of barley germplasm with multiple disease resistance.

University of Guelph, School of Rural Development and Planning, Ontario
- Role of women in resource management and household livelihood strategies.

University of Guelph, Ontario Agriculture College, Department of Plant Agriculture
- Modeling Sustainability of Cropping Systems based on Long-term Trials

University of Manitoba, Winnipeg
- Collaboration in tan spot disease

University of Saskatchewan, Saskatoon
- Genetic improvement of resistance to *Ascochyta* blight and Anthracnose in Lentil.
- Evaluation of chickpea for *Ascochyta* blight resistance.
- Evaluation of chickpea germplasm and their wild relatives.

DENMARK

Risø National Laboratory, Plant Biology and Biogeochemistry Department
- Genetic mapping in barley
- Barley pathology
- Integrated cereal disease management in Eritrea.

Danish Institute of Agriculture Sciences (DIAS)
- Yellow rust of wheat
- Integrated cereal disease management in Eritrea.

EGYPT

AGERI (Agricultural Genetic Engineering Research Institute), Cairo
- Development of transformation systems for wheat and barley: gene discovery for tolerance to abiotic stresses.
- Transformation systems for lentil, chickpea and faba bean.
- Assessment of factors leading to deterioration of fig trees in the dry areas of Egypt and development of virus free fig seedlings.

CLAES (Central Laboratory for Agricultural Expert Systems), Cairo, Egypt

FINLAND

Agricultural Research Center of Finland (MTT)
- Nutritional aspects of grain legumes

FRANCE

CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement)
- Bioeconomic and agro-pastoral community modeling studies in WANA.
- Socioeconomic studies of rangeland management in WANA.
- Global program for direct sowing, mulch-based systems and conservation tillage.

Institut National de la Recherche Agronomique (INRA)
- Morphophysiological traits associated with constraints of Mediterranean dryland conditions in durum wheat.
- Water balance studies in cereal-legume rotations in semi-arid Mediterranean zone.
- Collaboration on cereal cyst nematodes.
- Genotyping of crop wild relatives.
- Biological control and botanical pesticides against insect pests.
- Studies on salt tolerance in food legumes.
- Evaluating the performance of crop model STICS developed by INRA.

Institut Francais de Recherche Scientifique pour le Développement en Coopération (ORSTOM)
- Cooperation in the establishment of a network on water information.

Université de Paris-Sud, Labo Morphogénese Végétale Expérimentale
- Production of doubled haploids in bread wheat and barley

GERMANY

University of Bonn
- QTL analysis in barley
- Integrated approaches to sustainable land management in dry areas

University of Frankfurt am Main
- Genomics of cold and drought tolerance in chickpea and lentil

University of Hamburg
- Establishment of a barley transformation system

University of Hannover
- Development of transformation protocols for chickpea and lentil

University of Hohenheim
- Increasing the heterozygosity level of barley to exploit heterosis under drought stress

University of Karlsruhe
- Use of remote sensing and GIS for identification of water harvesting sites.

University of Kiel
- Assessment of information needs for development of water management models.
- Institutions of supplemental irrigation.
- Development of SSER markers in lentils.

ITALY

Catania University,
- Developing a decision support system for mitigation of drought impacts in Mediterranean regions.

Institute of Nematology, Bari
- Studies of parasitic nematodes in food legumes.

Istituto Sperimentale per la Cerealicoltura, Sezione di Fiorenzuola d'Arda
- Collaboration in mapping adaptation of barley to drought environments"

University of Tuscia, Viterbo.
- Diversity of storage proteins in durum wheat

University of Tuscia, Viterbo; Germplasm Institute, Bari; ENEA (Italian Research Agency for New Technologies, Energy and the Environment), Rome.
- Evaluation and documentation of durum wheat genetic resources.

JAPAN

Japan International Cooperation Agency (JICA)
- JICA's volunteers program supports research on small ruminant health and nutrition.
- Joint training program in management of water resources and improvement of water-use efficiency in dry areas.

Japan International Research Center for Agricultural Sciences (JIRCAS)
- Comparative genomics and cDNA microarray technology for the identification of drought and cold inducible genes in model plants.
- Evaluation of genetic resources and biotechnological approaches for the improvement of wheat germplasm tolerant to environmental stresses.

Kyoto University
- Collaboration in molecular characterization of wheat wild relatives

Tottori University
- Collaboration on human resource development programs for arid land sciences.

NETHERLANDS

Vrije Universiteit Amsterdam (Faculteit der Aard en Levenswetenschappen)
- Collaboration on groundwater research in Syria

Wageningen University
- Collaboration on land and water management research in Syria

Department of Plant Science, Laboratory of Plant Breeding, Wageningen
- Collaboration in mapping adaptation of barley to drought environments

NORWAY

Noragric (Agricultural University of Norway)
- Collaboration on soil and water management research in Syria

PORTUGAL

Estacao National de Melhoramento de Plantas, Elvas
- Developing lentil, faba bean, chickpea, and forage legumes adapted to Portugal's conditions.
- Evaluation of IZARIG irrigation management model for supplemental irrigation.

RUSSIA

All Russian Institute of Agricultural Biotechnology, Moscow
- Establishment of barley transformation system

The N.I. Vavilov All-Russian Scientific Research Institute of Plant Genetic Resources (VIR)
- Genetic resources exchange, joint collection missions and collaboration in genetic resources evaluation and documentation.
- Bread wheat eco-geographic diversity studies

SPAIN

University of Barcelona
- Durum and bread wheat stress physiology
- Barley stress physiology
- Mapping adaptation of barley to drought environments

University of Cordoba
- Durum grain quality

UdL-IRTA (University of Lleida and Institut de Recerca i Technologia Agroalimentaria - IRTA)
- Mapping adaptation of barley to drought environments

SWITZERLAND

Institut Universitaire d'Études du Développement (IUED), Geneva
- Sustainable dryland resource management in the arid margins of Syria.

Station Fédérale de Recherches Agronomiques de Changins (RAC), Nyon
- Duplication of *Lathyrus* genetic resources and data

Swiss Centre for International Agriculture
- Improving resistance to barley scald through understanding the processes that govern the evolution of *Rhynchosporium secalis* populations

Swiss Federal Institute of Technology (ETH), Animal Nutrition Department
- Feeding systems and quality of sheep milk products

University of Bern
- World Overview of Conservation Approaches and Technologies (WOCAT)

UNITED KINGDOM

Birmingham University
- Collaboration in advising students on *in situ* conservation.

Bristol University
- Analysis of the climatology of rainfall obtained from satellite and surface data for the Mediterranean basin.

CABI Bioscience
- Entomopathogenic fungi for Sunn pest control

Macaulay Land Use Research Institute
- Research planning on feeding systems for small ruminant production in the dry areas.
- Joint Ph.D. study on analysis of long-term rotational trials in sheep and fodder production in Syria together with Reading University, U.K.

Natural Resources Institute, University of Greenwich
- Sunn pest pheromones

University of Reading
- Gender analysis in the agricultural systems of WANA.
- Testing wooly-pod vetch in hillside project in Uganda.

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, Riverside
- Biodiversity of wheat wild relatives

University of California, Davis
- GL-CRSP (Global Livestock Collaborative Research Support Program): rangeland production and utilization in Central Asia.
- Developing chickpea cultivars with resistance to *Ascochyta* blight.
- Study of genetic diversity in natural populations of *Aegilops* spp.
- Study of genetic diversity and evolution in cultivated and wild lentil, pisum and chickpea

Colorado State University
- Testing for stripe rust in barley

Cornell University
- Use of molecular markers for genome mapping and marker-assisted selection for stress resistance in durum wheat.
- Spatial variability in lentil trials.

University of Delaware
- Use of information technology for improving water-use efficiency

DuPont Agric. Biotechnology
- Development of EST markers in wheat and lentils

Fort Valley State University, Georgia
- Strengthening teaching and research on sheep and goat production in Tunisia

University of Massachusetts
- Child nutrition in rural areas of Syria.

University of Minnesota
- Research on improving productivity of oats as priority forage crops

North Carolina State University, Department of Statistical Genetics
- QTL estimation for disease data

Oklahoma State University
- Collaboration in feasibility study for sustainable renovation of *qanats* in Syria

Oregon State University
- Molecular mapping of barley within the North America Barley Genome Mapping project.
- Identification of molecular markers associated with resistance to diseases of barley.

Purdue University
- GIS for watershed management in the arid regions of Tunisia

University of Missouri, Columbia
- Adaptation to drought and temperature stress in barley using molecular markers

TIGR (The Institute for Genomic Research)
- Development of functional genomics and single nucleotide polymorphism platforms for cereals and legumes

University of Vermont
- Use of entomopathogenic fungi for the control of Sunn pest in West Asia

University of Wisconsin
- Small ruminant production with emphasis in dairy sheep evaluation and crossbreeding.
- Sheep production in Central Asia

Washington State University
- The use of CropSyst simulation model in the WANA region for generalization of the site-specific research results for wider ecoregions.

USDA/ARS (US Department of Agriculture, Agricultural Research Service)
- Biological diversity, cultural and economic value of medicinal, herbal and aromatic plants in southern Tunisia

USDA/ARS Beltsville Agricultural Research Center, Beltsville, Maryland
- Development of bread wheat cultivars facilitated by microsatellite DNA markers

USDA/ARS Plant Stress and Water Conservation Laboratory, Lubbock, Texas
- Climatological analysis as a tool for agricultural decision-taking in dry areas.

USDA/ARS Stillwater, Oklahoma
- Russian wheat aphid resistance and biotypes

USDA/ARS Grain Legume Genetics and Physiology Research, Pullman, Washington
- Gene mapping of economic traits to allow marker assisted selection in chickpea.
- Exploitation of existing genetic resources of food legumes
- Inheritance and mapping of winter-hardiness genes in lentil for use in marker-assisted selection

USDA/ARS Plant Science Research Unit
- Research on improving productivity of oats as priority forage crops

USDA/ARS Western Regional Plant Introduction Station, Pullman, Washington
- Conservation of temperate food, pasture and forage legume biodiversity.
- Conservation and collection of plant genetic resources in Central Asia and the Caucasus

United States Wheat and Barley Scab Initiative
- Research network for the development of effective control measures that minimize the threat of *Fusarium* head blight (scab)

Appendix 6

Research Networks Coordinated by ICARDA

Title	Objectives/Activities	Coordinator	Countries/ Institutions	Donor Support
International and 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, ICRISAT 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; ICRISAT	ICARDA Core funds
SEWANA (Southern Europe and WANA) Durum Wheat Research Network	Cooperation between durum breeders and crop improvement scientists from southern Europe, West Asia and North	ICARDA Germplasm Program	Algeria, Jordan, Lebanon, Morocco,	ICARDA Core funds; France;

University of Vermont
- Use of entomopathogenic fungi for the control of Sunn pest in West Asia

University of Wisconsin
- Small ruminant production with emphasis in dairy sheep evaluation and crossbreeding.
- Sheep production in Central Asia

Washington State University
- The use of CropSyst simulation model in the WANA region for generalization of the site-specific research results for wider ecoregions.

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- Biological diversity, cultural and economic value of medicinal, herbal and aromatic plants in southern Tunisia

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SEWANA (Southern Europe and WANA) Durum Wheat Research Network	Cooperation between durum breeders and crop improvement scientists from southern Europe, West Asia and North	ICARDA Germplasm Program	Algeria, Jordan, Lebanon, Morocco,	ICARDA Core funds; France;

Title	Objectives/Activities	Coordinator	Countries/ Institutions	Donor Support
	Africa (SEWANA) in developing techniques and breeding material adapted to the Mediterranean environment and with high grain quality.		Tunisia, Turkey, Syria, France, Greece, Italy, Spain, Canada, USA	Italy
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; ISNAR	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

Sub-Regional Networks

Networks operating under the Nile Valley and Red Sea Regional Program (NVRSRP):

Title	Objectives/Activities	Coordinator	Countries/ Institutions	Donor Support
Control of Wheat Rusts: Sources of Primary Inoculums and Resistance to Yellow, Stem and Leaf Rusts of Wheat	Monitoring the physiologic races of rusts (stem, leaf and yellow rusts), their composition, frequency and virulence. Identifying the effective genes that condition resistance against the prevailing and newly developed rust races. Postulating resistant genes in the high yielding genotypes. Studying through forecasting studies the factors responsible for rust epiphytotics in each country. Demonstration on farmers' fields of improved wheat cultivars with resistance to different rust races.	ARC, Egypt	Egypt, Ethiopia, Sudan, Yemen, ICARDA.	IFAD
Management of Wilt and Root Rot Diseases of Cool Season Food Legumes	Identification of races of *Fusarium* wilt pathogens at national levels and their geographical contribution at the regional level. Development of integrated disease management measures, Demonstration of	EARO, Ethiopia	Egypt, Ethiopia, Sudan, ICARDA, ICRISAT	IFAD

Title	Objectives/Activities	Coordinator	Countries/ Institutions	Donor Support
	available control measures for wilt and root-rot diseases in legumes crops. Identification of sources of resistance to wilt and root-rots at national and regional levels.			
Integrated Control of Aphids and Major Virus Diseases in Cool Season Food Legumes and Cereals	Creation of data bases on the temporal and spatial population dynamics of viruliferous virus vectoring aphids. Identification of germplasm resistant to specific viruses. Development of integrated management practices that will decrease aphid populations and the incidence of the viral infections that they transmit to wheat, barley and faba bean.	ARC, Egypt	Egypt, Ethiopia, Sudan, Yemen, ICARDA	IFAD
Integrated Management of Chocolate Spot Disease of Faba Bean	Studies of integrated management of chocolate spot, using resistant cultivars and cultural practices. Evaluation on farmers' fields in Egypt and Ethiopia, of available IPM practices identified in on-station research and verification of their performance. Collection and characterization of isolates of *Botrytis* spp. at national and regional levels.	ARC, Egypt	Egypt, Ethiopia ICARDA,	IFAD
Thermotolerance in Wheat and Maintenance of Yield Stability in Hot Environments	Identification of physiological and morphological traits for improving wheat adaptation to heat. Development of heat tolerant high yielding cultivars and selection of the best for commercial production after demonstration of their yield potential on farmers' fields with the participation of farmers and extension workers.	ARC, Egypt	Egypt, Ethiopia, Sudan, Yemen, ICARDA.	IFAD
Drought and Water-Use Efficiency in Cereals and Food Legumes	Development and identification of high yielding wheat, barley, lentil and chickpea cultivars that require less water, tolerate moisture stress in irrigated areas and drought in rainfed areas. Development of improved production packages comprising moisture stress tolerant cultivars, effective irrigation regimes/moisture conservation systems and appropriate cultural practices to utilize water more efficiently.	ARC, Sudan	Egypt, Ethiopia, Sudan, Yemen, ICARDA.	IFAD
Socioeconomic Studies	Identification of production constraints for target crops in target environments in a participatory approach. Quantification of the impact and distribution of benefits from the use of improved technology at the farm level. Incorporation of socioeconomic research results in the technology generation process to improve the efficiency and effectiveness of agricultural research and the technology transfer process.	ARC, Sudan	Egypt, Ethiopia, Sudan, Yemen, ICARDA.	IFAD

Appendix 7

Financial Information

Audited Statement of Activity (US$ × 000)

	2003	2002
REVENUES		
Grants (Core and Restricted)	24,356	23,134
Other revenues and supports	806	1,091
Total revenues	25,162	24,225
EXPENSES		
Research	20,910	20,745
Training	1,044	970
Information services	720	730
General administration	1,212	1,051
General operation	2,034	1,731
Total expenses	25,920	25,227
Recovery of indirect costs	(760)	(998)
Net Expenses	25,160	24,229
EXCESS REVENUES OVER EXPENSES	2	(4)
ALLOCATED AS FOLLOWS:		
Unrestricted unappropriated assets	2	(4)
Surplus/(Deficit)	2	(4)

Statement of Financial Position (US$x000)

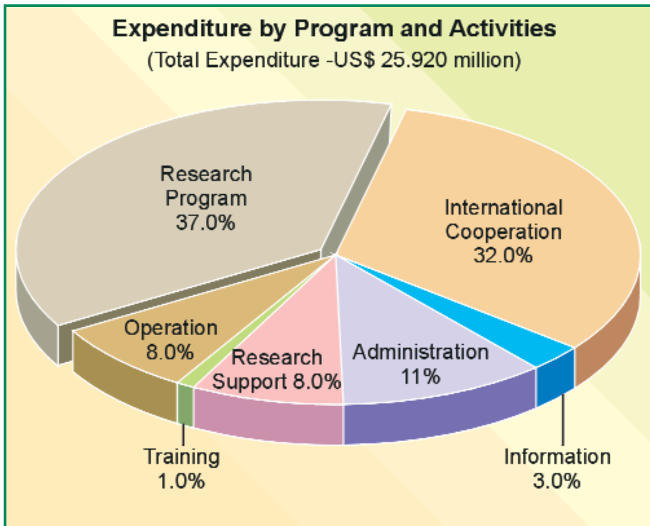
	2003	2002
ASSETS		
Current assets	25,633	25,291
Property & equipment	2,738	3,287
Total assets	28,371	28,578
LIABILITIES AND ASSETS		
Current liabilities	13,101	13,706
Long-term liabilities	3,712	3,316
Total liabilities	16,813	17,022
Net assets	11,558	11,556
Total liabilities & net assets	28,371	28,578

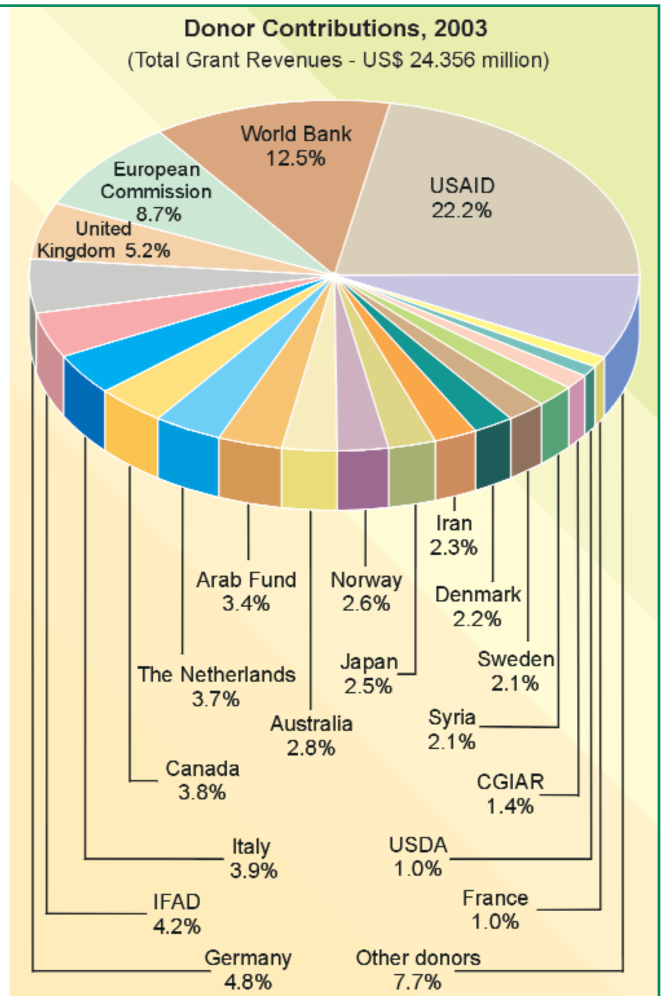
Statement of Grant Revenues, 2003 (US$x000)

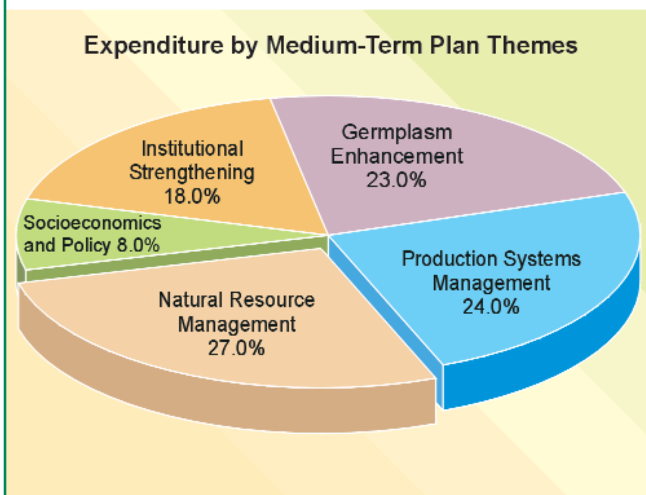
Donor	Amount
Arab Fund	816
Asian Dev. Bank	89
Australia*	679
Belgium*	106
Canada*	917
CGIAR	331
CIHEAM	7
China*	30
Denmark*	548
Egypt*	200
Ethiopia	17
European Commission	2,126
FAO	131
France*	239
Germany*	1,175
GM-UNCCD	61
IDRC	194
IFAD	1,035
India*	38
Iran*	564
Italy*	942
Japan*	619
Morocco	34
Norway*	624
OPEC Fund	93
Pakistan	113
Sweden*	521
Switzerland	209
Syria*	500
The Netherlands*	889
Turkey	20
UNDP	177
UNEP	35
United Kingdom	1,277
USAID*	5,400
USDA	244
World Bank*	3,043
Miscellaneous	313
Total	24,356

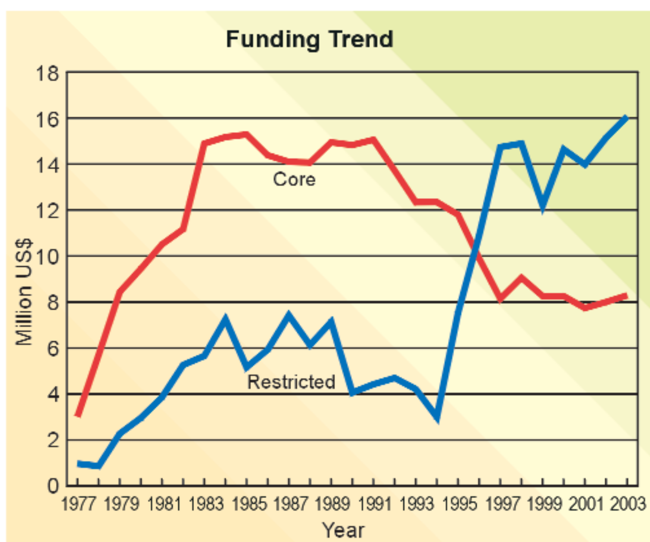
*Donors that provided core funds

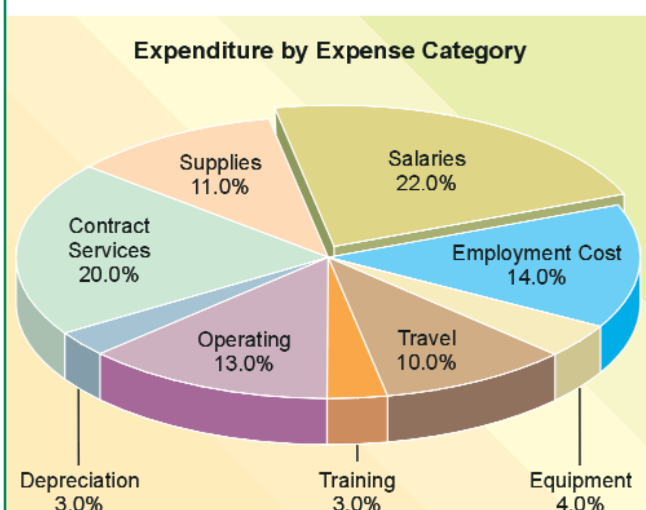
Financial Information











Appendix 8

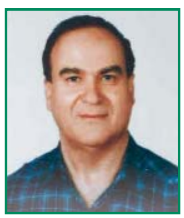
Board of Trustees

Five new members joined ICARDA's Board of Trustees in 2003: Mr Mohammed Bassam Al-Sibai, Dr Reiad Kasem, Dr Kjersti Larsen, Prof. Dr Magdy A. Madkour, and Dr David J. Sammons.

Mr Mohammed Bassam Al-Sibai

Mr Al-Sibai is an economist and a human resource and development specialist. He is currently the Deputy Head of State Planning Commission in Syria and is also serving as a Board Member of the Syrian Economic Science Association. From 1984 to 2002, Mr Al-Sibai worked as Deputy Director and then as Director of the Technical and Scientific Cooperation at the Syrian State Planning Commission. His research interests include population growth and distribution, economic growth, and the environment.

Dr Reiad Kasem



A specialist in animal production and breeding, Dr Kasem is the Director of International Cooperation in Syria's Ministry of Agriculture and Agrarian Reform. He has been responsible for human resource capacity building and forging international linkages. He has actively contributed to the World Food Program of the FAO. Dr Kasem has also served as a consultant for the Arab Company for Livestock Development (ACOLID), as well as for the UNDP. Dr Kasem has published several scientific papers in international journals on breeding and animal and forage production. His professional interests include income generation in relation to gender consideration in rural areas.

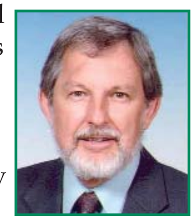
Dr Kjersti Larsen

A social anthropologist, Dr Larsen, is an associate professor at the Centre for International Environment and Development Studies at the Agricultural University of Norway. Dr Larsen's work focuses on African studies, migration, gender, social change, modernization, poverty issues, participatory methods and rural development. She has published a number of articles and reports, and lectured at various venues around the world. Dr Larsen has also worked as a consultant for the Norwegian Immigration Department, and designed and carried out courses, seminars, and workshops.

Prof. Dr Magdy A. Madkour

Prof. Dr Madkour is the President of the Agricultural Research Center (ARC), and Supervisor of the Agricultural Genetic Engineering Research Institute (AGERI) in Egypt. He helped to establish AGERI and has served as a member of many committees and boards including the Biotechnology Steering Committee at ICARDA. He was a member of the Technical Advisory Committee (TAC) of the CGIAR from 1997 to 2000. Prof. Dr Madkour is a plant pathologist and his research interests include using biotechnology and genetic engineering to produce plants with tolerance to abiotic and biotic stresses. Prof. Dr Madkour has written two textbooks, and published more than 100 articles in regional and international journals.

Dr David J. Sammons



Dr Sammons is the Associate Dean and Director for the International Programs in Agriculture at Purdue University, USA. He has worked on the development, evaluation and release of improved varieties of wheat and barley in the United States. He has published extensively, and has served as a panel member and speaker on international agriculture. Dr Sammons has received several grants from USAID and has worked in China, Honduras, Gaza and the West Bank, Kenya, and Tunisia. He is a technical journal reviewer for journals such as Crop Science and Agronomy Journal.

Full Board 2002

At the Annual General Meeting of the Board on 22-23 May 2003, the membership of ICARDA's Board of Trustees was as follows:

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(As of 31 December 2003)

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Dr William Erskine, Assistant Director General (Research)
Dr Elizabeth Bailey, Project Officer
Ms Houda Nourallah, Administrative Officer to the Director General and Board of Trustees
Mr Hembapura Tharanga De Silva, Internal Auditor

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Mr Essam Abd Alla Saleh Abd El-Fattah, Assistant Director of Corporate Services and Manager, Purchasing and Supplies

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Mr Ahmed El-Shennawy, Associate Director of Finance
Mr Mohamed Samman, Treasury Supervisor

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Dr Aden Aw-Hassan, Agricultural Economist
Dr Adriana Bruggeman, Agricultural Hydrology Specialist
Dr Eddy De Pauw, Agroclimatologist
Dr Luis Iñiguez, Senior Small Ruminant Scientist
Dr Asamoah Larbi, Pasture and Forage Production Specialist
Dr Theib Oweis, Water Management/Supplemental Irrigation Specialist
Dr Mustafa Pala, Wheat Based Systems Agronomist
Dr John Ryan, Soil Fertility Specialist
Dr Manzoor Qadir, Marginal Water Management Specialist
Dr James A. Tiedeman, Range Management Scientist
Dr Francis Turkelboom, Soil Conservation/Land Management Specialist
Dr Abdul Bari Salkini, Agricultural Economist/ Liaison Scientist
Dr Kamel Shideed, Consultant
Dr Ahmed Mazid, Agricultural Economist
Mr Markus Buerli, Junior Professional Officer
Dr Celine Dutilly-Diane, Junior Professional Officer, Socio-economics
Ms Birgitte Larsen Hartwell, Junior Professional Officer
Mr Tsuyoshi Takahashi, Associate Expert
Ms Inger Waldhauer, Junior Professional Officer
Dr Hanadi Ibrahim El-Dessougi, Post-Doctoral Fellow, Nutrient and Water Flows
Dr Wilko Schweers, Post-Doctoral Fellow, Land Management
Mr Akhtar Ali, Water and Soil Engineer
Ms Azusa Fukuki, Research Associate
Mr Adekunle Gabriel Ibiyemi, Senior GIS Analyst
Dr Roberto La Rovere, Researcher in Economics
Dr Malika Martini Abdelali, Research Associate, Socioeconomics and Gender Analysis
Dr Safouh Rihawi, Research Associate
Ms Monika Zaklouta, Research Associate
Ms Shibani Ghosh, Research Fellow
Ms Rahmouna Khelifi-Touhami, Research Fellow
Mr Alois Klewinghaus, Research Fellow, Land Management
Ms Katharina Lange, Visiting Research Fellow
Mr Haben Asgedom Tedla, Research Fellow, Land Management (BMZ/GTZ Project)

Germplasm Program

Dr Ali Abd El-Moneim, Forage/Legume Breeder and Acting Director
Dr Michael Baum, Biotechnologist
Dr Mustapha El-Bouhssini, Entomologist
Dr Salvatore Ceccarelli, Barley Breeder
Dr Stefania Grando, Barley Breeder
Dr Rajinder Singh Malhotra, Chickpea Breeder
Dr Miloudi M. Nachit, Durum Wheat Breeder
Dr Ashutosh Sarker, Lentil Breeder
Dr Amor Yahyaoui, Cereal Pathologist
Dr Moussa Guirgis Mosaad, Visiting Scientist Coordinator, ICARDA/Turkey Activities
Dr Lucas Brader, Sabbatical, Visiting Scientist
Dr Masanori Inagaki, Visiting Scientist
Dr Sripada M. Udupa, Biotechnologist
Dr Bassam Bayaa, Consultant, Legume Pathologist
Dr Shaaban Khalil, Consultant, Faba Bean Breeding

Dr Wafa Chouman, Consultant, Biotechnology
Dr Bitore Djumahanov, Post-Doctoral Fellow - Cereal Breeder/Geneticist (Tashkent)
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Mr Berhane Lakew Awoke, Visiting Research Fellow
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Dr Kenneth Street, Associate Expert
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Mr Colin Webster, Systems Programmer/Network Administrator
Mr Michael Sarkisian, Senior Maintenance Engineer
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Mr Ahmed Shahbandar, Assistant Farm Manager

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Appendix 10

Acronyms

AAAID	Arab Authority for Agricultural Investment and Development, Sudan
APAARI	Asia-Pacific Association of Agricultural Research Institutions
AARINENA	Association of Agricultural Research Institutions in the Near East and North Africa
ABRII	Agricultural Biotechnology Research Institute of Iran
ACIAR	Australian Centre for International Agricultural Research, Australia
ACSAD	Arab Center for Studies of the Arid Zones and Dry Lands, Syria
ADB	Asian Development Bank, Philippines
AFESD	Arab Fund for Economic and Social Development, Kuwait
AREO	Agricultural Research and Education Organization, Iran
AGERI	Agricultural Genetic Engineering Research Institute, Egypt
AOAD	Arab Organization for Agricultural Development, Sudan
APRP	Arabian Peninsula Regional Program
ASU	Afghan Survey Unit
CAC	Central Asia and the Caucasus
CACRP	Central Asia and the Caucasus Regional Program
CATCN	Central Asian and Trans-Caucasian Network
CGIAR	Consultative Group on International Agricultural Research
CIHEAM	Centre International de Hautes Etudes Agronomiques Mediterraneennes, France
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico
CIAT	Centro Internacional de Agricultura Tropical, Colombia
CIP	International Potato Center, Peru
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France
CLAC	Central Laboratory for Agricultural Climate, Egypt
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
ERF-FEMISE	Economic Research Forum—Euro-Mediterranean Forum of Economic Institutes
ESCWA	Economic and Social Commission for Western Asia
EARO	Ethiopian Agricultural Research Organization
FAO	Food and Agriculture Organization of the United Nations, Italy
FHCRAA	Future Harvest Consortium to Rebuild Agriculture in Afghanistan
GAP	Southeastern Anatolia Project, Turkey
GEF	Global Environment Facility
GEF/UNDP	Global Environment Facility/United Nations Development Programme
GFAR	Global Forum on Agricultural Research
GIS	Geographic Information Systems
GOSM	General Organization for Seed Multiplication, Syria
GRU	Genetic Resources Unit
GTZ	German Technical Cooperation Agency
HRP	Highland Regional Program
CRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
IDRC	International Development Research Centre, Canada
IFAD	International Fund for Agricultural Development, Italy
IFPRI	International Food Policy Research Institute, USA
IITA	International Institute for Tropical Agriculture, Nigeria
ILRI	International Livestock Research Institute, Kenya
IMPHOS	World Phosphate Institute, Morocco
INRA	Institut National de la Recherche Agronomique, France
IPGRI	International Plant Genetic Resources Institute, Italy
IPM	Integrated Pest Management
IRRI	International Rice Research Institute, Philippines
IWMI	International Water Management Institute, Sri Lanka
IWWIP	International Winter Wheat Improvement Project
JICA	Japan International Cooperative Agency, Japan
JIRCAS	Japan International Research Center for Agricultural Sciences
LARI	Lebanese Agricultural Research Institute, Lebanon

MAWR	Ministry of Agriculture and Water Resources, Uzbekistan
M&M	Mashreq and Maghreb
MRMP	Matrouh Research Management Project, Egypt
NAAS	National Academy of Agricultural Sciences, India
NARP	North Africa Regional Program
NARS	National Agricultural Research Systems
NASA	National Aeronautics and Space Administration, USA
NCARTT	National Center for Agricultural Research and Technology Transfer, Jordan
NGO	Non-Governmental Organizations
NVRSRP	Nile Valley and Red Sea Regional Program
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries, Austria
PPDRI	Plant Pests and Diseases Research Institute, Iran
SDC	Swiss Agency for Development and Cooperation, Switzerland
SPII	Seed and Plant Improvement Institute, Iran
TIIAME	Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent
TWAS	Third World Academy of Sciences, Italy
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
UNU	United Nations University, Japan
UN/WFP	United Nations/World Food Programme
UPOV	International Union for the Protection of New Varieties of Plants, Switzerland
USAID	United States Agency for International Development, USA
USDA	United States Department of Agriculture, USA
WANA	West Asia and North Africa
WARP	West Asia Regional Program, Jordan
ZEF	Center for Development Research, Germany

Appendix 11

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Investors in ICARDA, 2003

Listed in descending order of investment.
For more information, please refer to page 115.

1 USAID	15 Denmark	29 Asian Dev. Bank
2 World Bank	16 Sweden	30 GM-UNCCD
3 European Commission	17 Syria	31 Int. Nutrition Foundation
4 United Kingdom	18 CGIAR	32 ERF-FEMISE
5 Germany	19 USDA	33 India
6 IFAD	20 France	34 UNEP
7 Italy	21 Switzerland	35 Morocco
8 Canada	22 Egypt	36 China
9 The Netherlands	23 IDRC	37 Turkey
10 Arab Fund	24 UNDP	38 Ethiopia
11 Australia	25 FAO	39 Univ. of Saskatchewan
12 Norway	26 Pakistan	40 CIHEAM
13 Japan	27 Belgium	41 ESCWA
14 Iran	28 OPEC Fund	42 Austria

Front Cover:
Dry-area environments are harsh, stressful and variable. Combating desertification and increasing on-farm water-use efficiency are, therefore, key components of ICARDA's research agenda. ICARDA scientists work closely with national programs and farmers on soil and water conservation technologies, improved crop varieties and water-harvesting systems to ensure increased production and nutritional quality of food and feed, while preserving and enhancing the natural resource base. .

Back cover:
Top two pictures: Supplemental irrigation to increase crop productivity. *Middle, left:* Village-based Seed Enterprises in Afghanistan, promoted by ICARDA, are now producing seed themselves and contributing to a viable national seed system; *Middle, right*: A faba bean field infested by the parasitic weed, *Orobanche* spp. ICARDA is working on integrated management of this destructive weed. *Bottom, left*: A new chickpea variety, 'Narmin,' released in Azerbaijan. *Bottom, right*: An olive grove. Olives thrive in harsh environments with minimal water and provide additional income for farmers.

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ICARDA-/5000/Aug 2004