Annual Report 2008

International Center for Agricultural Research in the Dry Areas

ICARDA

About ICARDA and the CGIAR

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is one of 15 centers supported by the CGIAR. ICARDA's mission is to contribute to the improvement of livelihoods of the resource-poor in dry areas by enhancing food security and alleviating poverty through research and partnerships to achieve sustainable increases in agricultural productivity and income, while ensuring the efficient and more equitable use and conservation of natural resources.

ICARDA

ICARDA has a global mandate for the improvement of barley, lentil, barley and faba bean, and serves the non-tropical dry areas for the improvement of on-farm water use efficiency, rangeland and small-ruminant production. In the Central and West Asia and North Africa (CWANA) region, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming systems. It also works on improved land management, diversification of production systems, and value-added crop and livestock products. Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.

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

CGIAR

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

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Agricultural Research
in the Dry Areas

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

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Foreword

The year of 2008 marked the beginning of a new phase at ICARDA: the full implementation of the Center's *Strategic Plan 2007-2016*, and a renewed commitment to addressing the global challenges of food security, poverty alleviation and climate change in the dry areas.

It was also a year of adversity, both locally and globally. At ICARDA's main research station in Syria, the 2007/2008 cropping season experienced drought combined with wide variations in temperature, falling to -12°C in winter and rising to 37°C in the early spring. This was the driest season in 38 years, with only 210 mm annual rainfall compared with the long-term average of 340 mm. Countries in West Asia and North Africa harvested only 40 to 50% of their normal rainfed crop production. In these adverse conditions, we were pleased to see that lines of cereals and legumes developed jointly with our partners performed well.

2008 also witnessed global food-price and economic crises and the specter of widespread food insecurity. Many countries in the dry areas that ICARDA serves were severely affected due to their dependence on cereal imports to meet their food demands. Their vulnerability to such fluctuations in global markets is exacerbated by low agricultural productivity and the prospects of climate change. The food crisis was a reminder of the vital role that agricultural research plays in ensuring food security and sustainable development. The UN Secretary General urged nations to revitalize agriculture as a way of tackling the food crisis. *The World Development Report 2008: Agriculture for Development* underscored the importance of agriculture as the main engine of economic growth and rural development. ICARDA has been called upon by many national governments to assist in developing research and capacity development programs to enhance food security.

The 2007/2008 season at ICARDA was only one example of the intrinsic variability in climatic conditions, both within and between seasons, in dry areas and provides a foretaste of future conditions. Climate models predict even more variability, aggravating the problems already facing farmers – highly variable rainfall, frequent drought, extremes of heat and cold, fragile ecosystems beset by land degradation, salinization, loss of biodiversity, and a host of plant diseases and insect pests. ICARDA brings its past experience in addressing climatic variability to bear on tackling the effects of climate change more broadly, with greater emphasis on adaptation, mitigation, and ecosystem resilience. Many technologies developed by ICARDA and its partners will have direct and immediate benefits in strengthening communities' capacity to adapt to climate change.

This Annual Report presents highlights of the Center's achievements in 2008 and examples of the integrated research approach that ICARDA takes in addressing its goals of achieving sustainable increases in agricultural productivity and income, while ensuring the efficient and more equitable use and conservation of natural resources.

As we reflect on 2008, and the challenges that it presented, ICARDA is even more conscious of the importance of collaboration and partnerships, particularly with the national programs of the countries the Center serves, in improving livelihoods and alleviating poverty in the dry areas.

Guido Gryseels
Chair, Board of Trustees

Mahmoud Solh
Director General

Highlights of the Year

Early in 2008, escalating food prices turned the spotlight on agriculture. Across the developing world, poor families found that food staples were too expensive – and not always available, even at high prices. As the year progressed, the global financial meltdown threatened to reverse the gains made in eliminating poverty. And an even greater threat looms – the impact of climate change on agriculture and global food security.

Agriculture is now recognized as a top priority for economic growth and sustainable development. Heads of State, Ministers and representatives of 180 countries gathered in Rome for the *High-level conference on world food security: the challenges of climate change and bioenergy*, which urged the international community "to decisively step up investment in science and technology for food and agriculture".

This report provides an overview of how ICARDA contributes to these international efforts by using science to help achieve sustainable and equitable agricultural development that will ensure food security and alleviate poverty. ICARDA's research platform encompasses the non-tropical dry areas of the developing world. Climate models show that these dry areas are particularly vulnerable to the impacts of climate change. Water, already a limiting factor in agricultural production, will become increasingly scarce. Future harvests will be challenged by more variable and extreme temperatures, more frequent droughts, and the spread of pests and diseases into new areas. New technologies and strategies are needed to help rural communities adapt to this changing environment and to provide the tools needed to maintain agricultural production and promote economic growth.

Protecting biodiversity

Some of the world's most important staple food crops, and many fruits, vegetables, forage species and medicinal, herbal and aromatic plants originated, and were first domesticated, in the dry areas served by ICARDA. The Center helps preserve this unique diversity, both in its genebanks and in their natural habitat, and works with national research programs in using this diversity to develop new varieties and support rural livelihoods (see page 10).

For example, in 2008, scientists from ICARDA and Jordan collected wild species of wheat from very dry areas in Jordan. These will be invaluable in developing heat-tolerant and drought-tolerant varieties. In the oases of Morocco, a similar mission collected samples of little-known landraces of several crops, including two bread wheat landraces that are perhaps the last remaining varieties adapted to oasis environments.

To ensure that these resources remain available to future generations, ICARDA is a partner in a global initiative launched in 2008 – the Svalbard Global Seed Vault, located on a remote island in the Arctic Circle. A joint initiative by the Norwegian Government, the Global Crop Diversity Trust and the Nordic Gene Bank, the vault will collect and preserve a large part of the world's plant genetic resources. ICARDA has already placed over 30,000 accessions, or around 1.2 tons of seed samples, in the vault. Over the next three years another 100,000 accessions will be shipped to Svalbard, so that ICARDA's entire collection – one of the

Inauguration of the Svalbard Global Seed Vault, which will ensure that global germplasm resources will be preserved for future generations.

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world's most valuable and most diverse – will be preserved.

"Crop diversity will soon prove to be our most indispensable resource for addressing climate change impacts, and for meeting the food needs of a growing population."
Dr Cary Fowler, Executive Director, Global Crop Diversity Trust.

Several thousand crop accessions in ICARDA's genebank have been genotyped using molecular markers. The results are helping to identify novel genes that can be used in breeding programs, and to understand the genetic relationships between different genotypes. In collaboration with Australian and Russian scientists, ICARDA developed an innovative method for identifying specific traits from within these large collections (see page 12).

ICARDA is playing an important role in global efforts to conserve, document and utilize plant genetic resources for food and agriculture. In 2008, the Center completed a series of studies for a major FAO report, *State of the world's plant genetic resources for food and agriculture*. The studies also helped identify what further actions are needed to strengthen national capacities in plant genetic resource conservation.

Seed Hunter

This award-winning documentary film is about a topic that is vital for the future of the planet: finding seeds that may help save the world from its greatest ever crisis – a global food shortage brought about by man-induced climate change. Highlighting the work of ICARDA's genetic resources scientists, *Seed Hunter* won awards from Australia and Finland in 2008.

Combating the global threat of wheat stem rust

A new race of stem rust disease, Ug99, is spreading rapidly, threatening wheat production over a vast area from East Africa and West Asia to Europe and even North America. ICARDA is a partner in the Borlaug Global Rust Initiative, which was established together with CIMMYT, FAO, the US Department of Agriculture and Cornell University to fight a range of rust diseases, and particularly to contain the Ug99 threat. In 2008, ICARDA and its partners evaluated almost 10,000 wheat accessions for Ug99 resistance in Yemen. Several hundred accessions proved resistant and are being tested further. Similarly, in Ethiopia, over 3750 spring bread wheat lines were tested; 825 were resistant even under very high infection levels. ICARDA is also tracking the spread of the diseases through a series of trap nurseries and providing information to the Ug99 global monitoring system (see page 14).

Advances in plant breeding

The Center's plant breeders continue to develop improved, high-yielding lines with resistance to a range of stresses (diseases, insect pests, cold, heat, drought), targeted at specific environments.

These lines provide national breeding programs with valuable raw material for further testing and development. In 2008, these materials included 150 high-yielding bread wheat lines adapted to dry environments, (developed by ICARDA in partnership with CIMMYT and the Turkish national program), and 51 bread and durum wheat genotypes derived from crosses with wild wheat (*Aegilops* species), and suited to dry conditions. In Morocco, a joint study with the national research program identified 363 spring bread wheat lines with resistance to Hessian fly (a major endemic pest throughout North Africa) and good agronomic traits.

The Center's barley breeders are successfully building on the intrinsic hardiness of this crop. In 2008, despite severe drought in Syria (the driest year in 38 years), ICARDA's new barley lines yielded 1.2 to 1.7 t/ha in farmers' fields: 70 to 300% more than local varieties, and up to 43% more than the best check varieties.

Over 100 promising new faba bean lines were identified with resistance to two important diseases: chocolate spot and *Ascochyta* blight. These materials are now being multiplied and purified for further testing.

Molecular marker studies examined the genetics of resistance to yellow rust disease, and identified several specific genes that might confer resistance; including a gene known as Sr2 that confers durable resistance (a high proportion of ICARDA's elite wheat germplasm contains this gene). Another marker study provided new insights into the genes conferring resistance to the Russian wheat aphid. Apparently novel resistance gene(s) were detected in wheat landraces that could be effective against some of the more virulent aphid biotypes.

Putative markers linked to *Ascochyta* blight in chickpea were identified – a potentially major breakthrough, with global implications.

Impacts of new varieties

A study completed in 2008 shows that improved wheat varieties, developed jointly by the Turkish national research program, CIMMYT and ICARDA, contribute at least US$24 million per year to Turkey's economy. The study focused on five new varieties that now occupy 15% of the total wheat

Testing lentils for heat tolerance at Tel Hadya

Varieties released in 2008, developed from ICARDA germplasm

Crop	Country	Name	Characteristics
Barley	Iran	Mahor	Suitable for warm and semi-warm highland areas
Barley	Mexico	Doña Josefa	High yield, good malting quality
Durum wheat	Iran	Dehdasht*	Suitable for warm and semi-warm highland areas
Winter wheat	Tajikistan	Ormon*	High yield, good grain quality, resistant to yellow rust and other diseases
Winter wheat	Turkey	Nacibey*	Drought tolerant, high yield under rainfed conditions
Lentil	India	Moitree	Early maturing, resistant to rust and Stemphylium blight, suitable for relay cropping
Lentil	Eritrea	Bir Selam	Drought tolerant, early maturing, wilt resistant, widely adapted
Chickpea	Australia	Genesis-509	High yield, Ascochyta blight resistant, suitable for drought-prone environments
Chickpea	Turkey	Hisar-98	High yield, large seeds, Ascochyta blight resistant
Chickpea	Iran	Azad	High yield, Ascochyta blight resistant

* Developed jointly with CIMMYT

area across five major provinces. The new varieties give higher yields and net returns than older varieties, on average doubling the gross margin per unit of land (see page 42).

New lentil cultivars, originating from ICARDA improved germplasm, were tested and adapted to local conditions by the national breeding program of Bangladesh. A systematic government outreach program has ensured that the new varieties, within four years of being introduced, occupy 44% of the country's lentil area. Combined with improved agronomic practices, the new varieties more than doubled farmers' gross margins; the additional production is worth an estimated US$11.5 million per year.

Water and land resources

ICARDA is applying integrated, participatory approaches at pilot "benchmark" sites in several countries, to help communities manage their land and water resources sustainably. Two key elements in water management include rainwater harvesting, and more efficient irrigation methods such as supplemental and/or deficit irrigation. In combination, these methods can help conserve water, direct it to crops, trees or fodder shrubs – critical in drought-prone areas – and simultaneously arrest soil erosion. One approach combines mechanized construction of micro-catchments using a specially designed plow, state-of-the-art laser-guidance technology to align micro-catchments exactly with the contour line, and traditional water-harvesting practices that capture run-off. The approach has been successfully tested in Syria and Jordan, and is now being extended to five countries in North Africa: Algeria, Libya, Mauritania, Morocco, and Tunisia.

In Egypt, raised-bed technology introduced in an irrigated benchmark site increased water productivity in wheat crops by over 50%. Similarly, at a rainfed benchmark site in Morocco, new technology packages increased water productivity by up to 30%.

In Central Asia, a project on combating land and water degradation in the Aral Sea basin, implemented jointly with IWMI, was concluded in 2008. The project covered Kazakhstan, Uzbekistan, and Turkmenistan, and helped communities improve the use of saline water in agriculture; manage salt-affected land, particularly land affected by high levels of magnesium; and replace failing conventional drainage systems with more effective bio-drainage. Technology components have been proven in field trials. In Kazakhstan, for example, applying phosphogypsum to magnesium-affected soils doubled cotton yields. In Uzbekistan, mulching cotton with a thin layer of wheat straw on fields irrigated with saline water raised yields by up to 12% and water productivity by 14%. In Kazakhstan, matching the amount of nitrogen fertilizer to the salinity of irrigation water partly offset the negative effects of poor quality water.

Simulation modeling can help reduce research time and costs, and ICARDA scientists helped validate and fine-tune two models in 2008. They calibrated the CropSyst model (developed by Washington State University) and now use it to simulate wheat yield under different CO_2, temperature, and rainfall conditions, and to

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predict how supplemental irrigation can help wheat farmers adapt to climate change. A watershed hydrology model (Soil Water Assessment Tool, SWAT) developed by Texas A&M University, the US Department of Agriculture and others, was modified to include water-harvesting, and used to evaluate water-harvesting in a 270 square kilometer watershed in Tunisia.

Research on hydrology and erosion processes focused on the Karkheh river basin in Iran. ICARDA worked with national partners to compute water balances for two upstream watersheds, clearly demonstrating the huge potential for improving water productivity by managing water more effectively and selecting appropriate cropping systems. The studies also measured tillage erosion and modeled long-term erosion scenarios. A 'basket' of 13 new technologies was introduced in eight communities in the river basin, and tested by over 200 farmers. The project is a prime example of how to combine strategic research with community-driven participatory and adaptive research.

The Syrian Government used ICARDA's broad expertise to address severe degradation of the Jabbul salt lake, an internationally important wetland recognized under the Ramsar convention. Studies concluded in 2008, with the development of a detailed management framework for the wetland, integrating resource management with livelihood options.

Conservation agriculture

The principles of conservation agriculture – minimum soil disturbance through zero-tillage; retention of vegetative cover through stubble mulching; use of new varieties; and diversification of crop rotations – aim to maintain the productivity and sustainability of farming systems. In 2008, ICARDA, together with national research and extension agencies and with funding from ACIAR, tested and promoted agronomic and conservation tillage packages in Iraq and Syria. At all sites, zero-till sowing was more productive and profitable than conventional sowing.

One major constraint to adoption of conservation agriculture on small farms has been the lack of available machinery. ICARDA has now identified local manufacturers in Syria and worked with them in developing and testing low-cost prototype zero-till planters using a modified Indian design. Engineers and farmers alike agree that, with a few modifications, these have great potential for commercialization.

Various conservation agriculture practices – permanent-bed-planting, intercropping, residue cover (mulching), and seeding of wheat into standing crops – were assessed in Central Asia and the Caucasus. Minimum tillage is now being practiced on more than 7.7 million hectares in Kazakhstan.

Livestock and livelihoods

Animal diseases are a major constraint to small-scale livestock producers; they create trade barriers and jeopardize marketing opportunities. A joint project with ILRI studied small ruminant diseases and health delivery systems. The results, shared with national development agencies and policy makers, are helping to maximize marketing opportunities for small-scale livestock owners in dry areas to improve livelihoods. Ongoing research continues to develop alternative low-cost, high-nutrition feed options to improve animal health and productivity, and develop community-based breeding schemes tailored to smallholder conditions.

A three-volume series describing genetic diversity of small ruminant breeds in the world's dry areas.

A new book describing the indigenous breeds of small ruminants (sheep and goats) in Central Asia and the Caucasus was published in 2008. This comprehensive volume, which brings together such information for the first time, is the third in a series; the previous volumes covered the breeds in North Africa and West Asia. With this third volume, we now have comprehensive documentation of the unique small ruminant diversity in the world's non-tropical drylands. Such information has supported efforts to rescue threatened traditional breeds in North Africa (see page 36). ICARDA is using these indigenous breeds to restore the livelihoods of vulnerable households, particularly female-headed households, by combining improved husbandry methods with value addition and better market opportunities (see stories on pages 38, 40).

Socio-economic and policy research

To be viable and sustainable, agriculture must be profitable. This was the basis of a major study supported by IFAD and implemented with national partners in Egypt and Morocco. Value-chain analysis focused on specific horticultural crops to better understand markets, price trends, competitiveness and related issues. The study helped identify new market opportunities for small-scale farmers in both countries, and has potential application to

similar farming systems throughout the dry areas. Similar work elsewhere in North Africa focused on the market (and livelihoods) potential of herbal, medicinal, and aromatic plants.

Acutely aware of the different roles of men and women in agriculture and the differential impacts that technological change can have on men and women, ICARDA has expanded its research in social and gender analysis. Studies have examined the role of women in agriculture, and factors such as division of labor, household dynamics, and the impact of migration on women. Together with IDRC-Canada, ICARDA held an international workshop on *Strengthening regional approaches to gender and social analysis* that laid the foundation for a broader program to strengthen national research capacity in social and gender issues in the Near East and North Africa. A new initiative on *Gendered migration and agriculture in the dry areas*, a case study in Syria, with support from IDRC, will examine the impact of rural-to-urban migration on livelihoods and natural resource management.

Rebuilding agriculture in Afghanistan

The Center and its partners continued to support farmers, community organizations, and government initiatives to rebuild Afghan agriculture. Research on seed delivery systems led to an innovative approach – village-based seed enterprises (VBSEs) – that is helping to create agribusiness opportunities for farmers, and rapidly disseminate seed of improved varieties of a range of crops. Seventeen such enterprises were established in three provinces. All are financially viable. This approach has been transferred as an international public good to Egypt, Eritrea, and Pakistan. Other ongoing initiatives focus on improving livelihoods by diversifying production systems and adding value to agricultural products: mint, saffron, dairy products, and others. The Center worked closely with national research and extension agencies, NGOs, and local communities to not only introduce technologies but also establish and train farmer groups and producer associations.

Mr Moola Ahmad, President of the Roobabi Agricultural Co-operative in Afghanistan expressing his gratitude to ICARDA and CIP for supporting farmer-entrepreneurs

"Everywhere farmers are very happy with the support provided by ICARDA and the USAID program. We congratulate the team for their extremely useful work: introducing high yielding varieties, organizing farmers for seed production, and developing small agro-industries for processing and value addition of mint and other medicinal plants." H.E. Fazal Rahim, Provincial Assembly of Nangarhar Province, Afghanistan, inaugurating the Behsood VBSE seed store.

New initiatives

Major initiatives in research-for-development were launched in 2008.

The *Water and Livelihood Initiative* brings together partners in seven countries (Egypt, Iraq, Jordan, Lebanon, Palestine, Syria, and Yemen), ICARDA, IWMI, and five US universities, to build a new long-term program to address water scarcity in North Africa and the Near East. Currently supported by USAID, the initiative aims to strengthen cooperative management of shared water; support governments in strengthening policies and regulations for more efficient water use; protect the quality of water resources; improve institutions; and encourage greater stakeholder participation in water management.

To address water scarcity, water quality deterioration, and abiotic stresses, such as drought and salinity, a multi-partner project on *Sustainable water use: securing food production in dry areas of the Mediterranean region*, supported by the European Commission, was launched at ICARDA in 2008. Led by the University of Copenhagen, Denmark, in partnership with ICARDA and research institutes from Australia, Egypt, Italy, Morocco, Portugal, Turkey and UK, the project aims to improve productivity and sustainability by developing more diverse farming systems in non-European Mediterranean countries.

Highlights of the Year

Heads of Turkish research institutes visiting ICARDA to learn more about the Center's research activities

Following a successful review of an earlier project to strengthen agricultural production in Iraq, supported by AusAID and ACIAR, a second phase of the project on *Development of conservation cropping systems in the drylands of northern Iraq* began in 2008. It focuses on testing and promoting conservation agriculture methods in Iraq, to improve soil quality and sustainability of farming systems. In addition to the national research system and the University of Mosul, partners include the Australian universities of Adelaide and Western Australia, and the Western Australia Department of Agriculture and Food, which are hosting Iraqi graduate research students.

ICARDA and IFPRI are partners in an *Economic analysis of sustainable land management options in Central Asia*, part of the Central Asian Countries Initiative on Land Management supported by the Asian Development Bank. The study will assess the economic feasibility, costs and benefits of alternative land management options in Central Asia and China.

Thanks to ICARDA's new varieties, this lentil famer has been able to build a house and send his children to school. He plans to buy a mini-truck to transport his grain to town

ICARDA joined other international partners in a major new initiative on *Durable rust resistance in wheat*, led by Cornell University and supported by the Gates Foundation. In a complementary project supported by the USAID Famine Fund, ICARDA will lead the production of seed of wheat varieties resistant to Ug99 for distribution to smallholder farmers in Egypt, Ethiopia, and Pakistan.

International events

International conferences and meetings bring together scientists from different disciplines and different countries, to share ideas and experiences. They help not only to advance research but also contribute to change by directly influencing policy makers. In 2008, ICARDA co-sponsored several international events.

The *10th International Barley Genetics Symposium* was organized in Alexandria, Egypt, jointly by ICARDA and the Bibliotheca Alexandrina. The Symposium, which is the most important forum for barley scientists, brought together over 200 participants from 43 countries who discussed production trends, recent research results, and future research priorities (especially in relation to climate change adaptation and biofuels). ICARDA's Principal Barley Breeder was elected Chair of the Organizing Committee of the next Symposium, to be held in China in 2012.

The *Ninth International Conference on Development of Drylands* was also held in Alexandria, cosponsored by ICARDA, the Bibliotheca Alexandrina, the Agricultural Research Center of Egypt, and a number of other agencies. The conference, which focused on development issues in the context of climate change, was attended by 450 participants from 42 countries, and 19 international and regional organizations. The discussions prepared the ground for regional initiatives to develop policies, institutional reforms, and partnerships for sustainable management of scarce natural resources.

An international workshop on *Poverty assessment and mapping in dry areas: Implications for better targeting the impact of agricultural R&D investments* was organized jointly by ICARDA, IFAD, and the World Food Program. The participants included policy makers and heads of national research centers from Egypt, Jordan, Sudan, Syria, Tajikistan, and Yemen. The six countries agreed to establish a regional research project to use GIS and other new tools to improve poverty mapping and assessment in dry areas, and thus target agricultural R&D more effectively towards the rural poor.

"The Tajikistan government strongly supports this initiative; and will work with ICARDA to expand research collaboration on poverty mapping. We believe the results will benefit not just our country, but the entire developing world."
Dr Mahmattoir Zakirov, Minister for Land Management, Government of Tajikistan.

Dr Mangala Rai, Director General, ICAR, lighting the traditional lamp at the inauguration of ICARDA's office in New Delhi, India

Expanding partnerships

Partnerships are central to ICARDA's mission, and the Center works closely with a wide range of stakeholders. These partnerships continue to expand.

In 2008, ICARDA opened its South Asia Regional Office in New Delhi, India, to coordinate the Center's activities in the dry areas of South Asia and China. The Delhi office will also become a hub for ICARDA's legume research, given the importance of pulses as the main source of dietary protein in South Asia.

"I see vast scope for collaboration, a partnership where India and ICARDA together can help many countries, especially in the CWANA region and Africa."
Dr Mangala Rai, Director General, Indian Council of Agricultural Research.

In China, ICARDA, ICRISAT, and the Chinese Academy of Agricultural Sciences signed a tripartite agreement to establish a Joint Centre of Excellence for Dryland Agriculture.

In 2008, ICARDA's Nile Valley and Red Sea Regional Program became the Nile Valley and Sub-Saharan Africa Regional Program, reflecting the new, broader scope of activities. Two new offices – in the Sudan, opened in 2008 and Ethiopia, soon to be opened – will play key roles in strengthening collaboration in Africa.

In North Africa, partnerships with Libya are being expanded following a series of high-level meetings in 2008 that ended in a large research project to improve food security and livelihoods in rural areas. Collaborative research will focus on water harvesting, wheat and barley improvement, and small ruminant production.

In the Arabian Peninsula, a new phase of the program has been launched, to scale out research results to farmers. Technology packages will cover three key areas: more efficient use of water, conservation and rehabilitation of rangelands, and reduction in pesticide use in protected agriculture. The regional project on date palm in the Gulf countries, supported by the Gulf Cooperation Council, was also extended to a second phase. The project aims to improve date palm production as well as post-harvest handling and processing in the region, which produces almost 30% of the world's dates.

ICARDA played a key role in establishing a new regional partnership: the 10 member countries of the Economic Cooperation Organization (ECO) region have announced the formation of a new regional seed association that will stimulate seed industry development, dissemination of new varieties, and food and seed trade across the region (see page 25).

The CGIAR's two dryland research centers, ICARDA and ICRISAT, joined other partners in a new consortium on Dryland Science for Development to boost global efforts to tackle the development challenges facing dry areas. The other core partners are European DesertNet, the EC's Joint Research Centre - Institute for Environment and Sustainability (JRC-IES), and the UN University's International Network on Water,

Environment and Health (UNU-INWEH). The consortium is currently working with the UN Convention to Combat Desertification (UNCCD) to help develop practical recommendations to support decision-making in land and water management.

New and expanded partnerships are helping to scale out improved technologies, such as hydroponics systems, across the Arabian Peninsula.

Science Week

ICARDA's research portfolio is continually reviewed and fine-tuned, through consultations within the Center and with our partners. This process was intensified in 2008. In addition to the traditional planning meetings, we conducted the first-ever Science Week, focusing on a globally important issue – adaptation to climate change. The aim was to review the current research portfolio, and identify areas where the Center

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Science Week brought together ICARDA staff from all locations, and international guest speakers from Austria, Australia and Kenya, to brainstorm on new directions for research

could best contribute to the global effort to help farmers adapt to climate change. Interactions with guest speakers from ILRI, the International Institute for Applied Systems Analysis, Austria, and the University of Western Australia sparked fresh ideas, and helped sharpen the Center's research strategy.

International awards

ICARDA's programs and staff were recognized by the global scientific community through several awards:

- The CGIAR Program for Sustainable Agricultural Development in Central Asia and the Caucasus, convened and hosted by ICARDA and implemented by a consortium of the national programs of the region, eight CGIAR Centers, and other international research institutes, won the 2008 CGIAR King Baudouin Science Award for Outstanding Partnership. The award, given every two years for research partnerships that generate large-scale impacts, recognizes the vital role that the Program has played – through research, and institution building – in strengthening research and agricultural production systems in Central Asia and the Caucasus.

The CGIAR-CAC Program won the King Baudouin Science Award for Outstanding Partnership

- Dr Mahmoud Solh, Director General, was awarded the title of Honorable Professor by the Saken Seifullin Kazakh Agro Technical University, Kazakhstan.
- Dr R.S. Malhotra, veteran chickpea breeder, received Fellowships from two international professional bodies: the American Society of Agronomy and the Crop Science Society of America.
- Dr John Ryan, soil scientist, won the prestigious International Service in Crop Science Award for 2008; he was also made an Honorary Member of the International Union of Soil Scientists.

Dr Mahmoud Solh, Director General , with Dr Aitbay K. Bulashev, President of the Saken Seifullin Kazakh Agro Technical University

Research Portfolio

ICARDA's new 10-year Strategic Plan re-aligns ICARDA's research portfolio to better respond to climate change, food insecurity, desertification, and other emerging challenges in the non-tropical dry areas. The strategy is underpinned by ICARDA's three decades of experience in the dry areas of developing countries.

In 2008, ICARDA directed its research portfolio to address both existing and emerging problems and exploit new opportunities. Programs spanned the entire research-for-development continuum to make sure that research outputs are relevant, and can be used efficiently for the benefit of resource-poor farming communities in non-tropical dry areas.

The Center's research is implemented through four thematic programs, as outlined below.

Biodiversity and Integrated Gene Management

The program aims to conserve the biodiversity of globally important agricultural plant species originating in dry areas and to use those resources in improving food security, nutrition and livelihoods. Research focuses on the conservation, characterization, and evaluation of the genetic resources of durum and bread wheat, barley, chickpea, lentil, faba bean, and forage and pasture crops; germplasm enhancement, employing new genetic research methodologies and biotechnological tools; integrated plant disease and pest management; and strengthening seed production and delivery systems to enhance adoption of new varieties.

Integrated Water and Land Management

This program aims to improve the management of scarce water resources and combat desertification and land degradation. It is developing technical, institutional and policy options and strategies for the sustainable, equitable, and economic use of all water sources to improve water productivity in both rainfed and irrigated production systems, and for improved land management and drought mitigation.

Diversification and Sustainable Intensification of Production Systems

Rural livelihoods can be transformed, and risks reduced, by intensifying and diversifying traditional production systems. Research in this program focuses on improving cropping systems management with better agronomic practices, improving the management and productivity of integrated crop-livestock-rangeland production systems, strengthening market linkages, supporting diversification into higher value crops, and generating income by adding value to crop and livestock products.

Social, Economic and Policy Research

A deeper understanding of rural poverty, livelihood strategies, and gender helps to target research and development investments and enhance the uptake and impact of

research outputs. The program encompasses analysis and mapping of the determinants of poverty coupled with research to identify pathways out of poverty, value chain and market analysis, develops policy and institutional options to improve livelihoods, identifies barriers to the adoption of new technologies, and conducts assessment of the impacts of the Center' research.

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

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

When researchers need to introduce new traits into crop plants it is vital that they have access to landraces that may contain just the traits they need. Here ICARDA breeders at Tel Hadya are evaluating landraces and wild relatives for drought tolerance

Pre-breeding lines being evaluated for drought tolerance at Breda research station

Unearthing hidden wealth in biodiversity

Overview

The biological diversity of drylands is rich in cultivated landraces and wild relatives of globally important food crops. But dryland ecosystems are fragile and much of their biodiversity is threatened.

ICARDA and its partners have therefore developed a new strategy to collect and conserve important diversity. This strategy has already been applied successfully to bread wheat adapted to cope with hot dry conditions and will now be applied to a broad range of other cereal and field crops.

But it's not enough just to conserve biodiversity in genebanks and *in situ* (where that biodiversity is found on the ground). ICARDA's work in Jordan, Lebanon, Palestine and Syria showed farmers that it is worthwhile not only to conserve biodiversity but to use local landraces – an important step forward in improving livelihoods and safeguarding plant genes for the future.

Making sure important biodiversity isn't lost

Genetic diversity within species supplies the building blocks for developing crops to cope with the threats of drought, extreme temperatures and other adverse effects of climate change. Plant breeders also use genetic diversity to select characteristics, such as high yields or resistance to pests and diseases. But it's not possible to conserve everything. Choosing what is important to conserve amongst the huge number of native species and landraces is a daunting task.

To overcome this problem, ICARDA, working with partners, applied the Gap Analysis method. This is used to identify gaps in the conservation of important species or strains with special attributes, such as drought tolerance. To do this, they analyzed what is already conserved in genebanks and *in situ*, and carried out eco-geographic surveys in Jordan, Lebanon, Syria and Palestine. They found gaps in the *in situ* conservation of landraces and wild relatives of wheat, barley, chickpea, lentil, and many fruit and neglected trees, since most of the protected areas did not target the wild relatives of these crops.

This information allowed the researchers to look for native species and landraces to fill gaps in genebank collections. They also identified areas where wild relatives of cereal, legume and fruit crops could be conserved *in situ* and advised farmers on the best ways of managing these areas.

This method is proving to be very good at identifying unique genetic material that might disappear, from distinct ecological niches. For example, ICARDA and INRA-Morocco collected bread wheat varieties from oases where the wheats had evolved under very hot conditions. The oasis wheat is a brand-new source of resistance to heat. Using this method, ICARDA is reducing the odds that important genetic traits will be lost for ever.

Unearthing hidden wealth

ICARDA not only makes sure that important genetic diversity is conserved, but also distributes over 25,000 accessions each year for researchers worldwide to work on. Around the world, scientists are exploiting the genetic diversity conserved in the ICARDA genebank to produce disease-resistant, high-yielding, and adapted cultivars suitable for local environments.

To speed up the process, ICARDA breeders thoroughly explore wild relatives and landraces in the genebank so they can offer researchers the accessions most likely to have the traits they are looking for. They have found new genes in wild *Triticum* and *Aegilops* species that are a rich source of valuable traits and broaden the genetic base for resistance to biotic and abiotic stresses in wheat. In an important breakthrough, ICARDA researchers have identified sources of genetic resistance to Sunn pest at the seedling stage (see page 12).

Using Gap Analysis, ICARDA is reducing the odds that important genetic traits will be lost for ever

Researchers have transferred valuable traits to improved durum and bread wheats, including resistance to yellow rust and leaf rust, drought tolerance, early maturity, height, and larger spikes and tillering. Some of the most promising lines combine several valuable traits. Cham5*2/*T. boeoticum* 500648 and Haurani*2/*T. boeoticum* 500652, for example, combine resistance to three different pests and diseases: Russian wheat aphid, Sunn pest, and yellow rust.

Promising lines performed well at ICARDA's Tel Hadya and Breda (Syria) experimental sites under the severe drought experienced in 2008. As a result, ICARDA stepped up work to identify drought-tolerant material in the genebank. Researchers evaluated 200 accessions of *Aegilops tauschii* at Breda and Tel Hadya in 2008. Of these, 19 accessions, mainly from Afghanistan, Iran and Pakistan, showed good tolerance to drought. These will be used in over 100 new crosses with drought-tolerant durum wheat landraces and improved lines to develop a new set of synthetic hexaploid bread wheats.

More diversity in the crops farmers grow means fewer risks and higher returns. But the great diversity of landraces and cultivars, built up over thousands of years of traditional farming, is dwindling.

Many local landraces have been forgotten. The seed stocks of local crop varieties are vanishing. Today, about 30 crops provide 95% of the world's food supply with eight plant species making up 75% of our diets. But old landraces and cultivars will be significant in adapting important agricultural crops to climatic variability and change in agro-ecosystems.

The best way of conserving landraces is for farmers to keep on growing them in the regions where they evolved. Landraces are well adapted to local conditions and farming practices. But they are often abandoned because they are less productive than improved varieties under high input conditions.

To improve the prospects for conserving landraces on farm, ICARDA developed a holistic approach. This takes into account all the factors that make it worthwhile for farmers to continue to use local landraces. Researchers worked with farmers on ways to improve harvests of landrace crops and then add value. Together they selected local landraces of crops and fruit. They developed ways of producing quality seed and seedlings, and using water harvesting and integrated pest management to improve yields. Value was added to wheat by producing burghul and frikeh; to fruit by making it into compotes, jams and syrups; and to the end-products by attractive labeling and packing.

ICARDA is now using this holistic approach to encourage communities in Yemen to conserve and use the landraces of 10 major crops. Without this encouragement, farmers would stop growing them and many would simply disappear. This approach marks an important step forward in linking the conservation of biodiversity to the use of biodiversity and can now be applied in other areas.

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Partners

- Institut National de la Recherche Agronomique, Morocco
- World Bank Rainfed Agriculture and Livestock Project, Yemen
- Agricultural Research and Extension Authority
- General Seed Multiplication Corporation, Yemen

Sunn pest is a leading cause of low yields and crop losses can reach 100%. If as little as 2-3% of the grain in a crop has been affected, the entire lot of grain becomes unsuitable for baking

Bread and durum wheat lines selected by FIGS were evaluated against Sunn pest at Tel Hadya

FIGS points the way to Sunn pest resistance

Overview

Plant breeders will increasingly need useful breeding traits to meet challenges in future agroecosystems. But finding the one trait they need among the more than 7.2 million accessions held in the world's genebanks is a daunting task. ICARDA's genebank holds more than 133,000 accessions, including around 33,500 accessions of wheat and related species.

This is where FIGS – the Focused Identification of Germplasm Strategy, developed by ICARDA's Genetic Resources Section in collaboration with an Australian–Russian team – comes in, by enhancing researchers' ability to locate traits in large germplasm collections.

FIGS was set to work in the ICARDA genebank to find sources of resistance to Sunn pest (*Eurygaster integriceps*), the major pest of wheat in West and Central Asia and eastern Europe. FIGS identified 534 likely accessions. Initial field screening reduced these to 57, and advanced screening resulted in nine entries with resistance to Sunn pest at the vegetative stage. These will form an important part of integrated pest management to reduce populations of adult insects.

These nine entries are the first wheat sources found with good levels of resistance to Sunn pest at the vegetative stage. They are now being used in ICARDA wheat breeding programs to develop wheat varieties resistant to Sunn pest feeding at the vegetative stage.

How FIGS finds those elusive traits

FIGS is based on the premise that the environment strongly influences gene flow and natural selection and consequently the geographic distribution of organisms. FIGS creates 'best-bet' trait-specific subsets of material by passing accession-level information, especially agro-climatic site information, through a series of filters that increase the chances of finding the adaptive trait of interest. ICARDA's genebank is particularly responsive to the FIGS approach since it is unique in the CGIAR system in having up to 70% of its collections geo-referenced. The ICARDA GIS unit can also provide a detailed environmental profile for any collection site in the whole of Eurasia.

FIGS has already successfully captured tolerance to biotic and abiotic stresses in relatively small, targeted subsets of germplasm (see box). In the latest challenge – to identify traits for Sunn pest resistance in wheat landraces – the FIGS filter process first

Recent FIGS successes

Powdery mildew resistance
A FIGS best-bet set of 1320 wheat accessions was supplied to Zurich University for powdery mildew screening. They found 211 accessions that were resistant to at least one of the four mildew isolates used in the screening. Later molecular studies, which focused on the *Pm3* allele, identified 15 new *Pm3* allelic sequences and at least two new functional genes.

Resistance to Russian wheat aphid
In screening sets of 500 accessions for resistance to the Syrian Russian wheat aphid biotype (the most virulent version known), FIGS led to the identification of 12 resistant accessions. Subsequent molecular analysis, using known markers linked to Russian wheat aphid *Dn* resistance genes, showed that a new source of resistance had been discovered.

Salinity tolerance
The FIGS approach was also used with a core set of bread wheats, to identify a best-bet subset of 320 accessions for salinity tolerance. These accessions were then tested by exposing them to salty water (100 mM NaCl, one-third of the salt level in seawater) for 10 days, then measuring the sodium (Na) content of the leaves. Researchers found that 21% had a desirable low leaf sodium content (less than 3 mg/g of dry matter). Yet only 3% of the accessions in the core set had such low levels – which shows just how effective FIGS can be in finding material that can overcome abiotic constraints.

Nine accessions identified through FIGS are the first wheat sources found with good levels of resistance at the vegetative stage to Sunn pest

screened for accessions from areas where Sunn pest has been reported and selected one accession per site.

Screening the accessions from FIGS in the field

The 534 accessions identified by the FIGS filtering process were field screened at the ICARDA research station at Tel Hadya during 2007. In the initial evaluation, 10 seeds per hill were planted, in an augmented design, with bread wheat cultivar 'Cham 6' as a susceptible check every 10 test entries. Plants were covered by mesh screen cages and infested with three adult Sunn pests per hill in mid-March, the time when they usually migrate to wheat fields.

Four weeks after infestation, plants were evaluated for damage from Sunn pest feeding at the vegetative stage. The promising entries (54 bread and 3 durum wheat lines) were re-evaluated in 2008, using the same screening procedure. Two susceptible checks (bread wheat cultivar 'Cham 6' and durum wheat line ICDW-7667) and two resistant checks (bread wheat line ICBW-209273 and durum wheat line SC-20831) were included.

The nine wheat accessions selected from the 2008 advanced evaluation had significantly less damage and stunting ratings than the two susceptible checks. The best accessions were five bread wheats from Afghanistan (IG-139431, IG-139883, IG-139814, IG-139835, and IG-139753). Another three bread wheat accessions (IG-139770 and IG-139558 from Afghanistan, and IG-140411 from Tajikistan) and a durum wheat landrace (IG-140368 from Tajikistan) were also selected as moderately resistant.

FIGS opens the way to future research on Sunn pest resistance

These nine accessions identified through FIGS are the first wheat sources found with good levels of resistance to Sunn pest at the vegetative stage in the ICARDA wheat collection. They are being used in ICARDA wheat breeding programs to develop resistant varieties against overwintered Sunn pest adults, which damage wheat at the vegetative stage (shoot and leaves). Resistance at this stage could be important in reducing overwintered Sunn pest adult populations, as well as nymphal and new generation adult populations, which reduce wheat quality by feeding on spikes (grains). The introduction of wheat varieties carrying resistance at the vegetative stage should be one component of a total integrated pest management program against Sunn pest.

Since all the accessions resistant to Sunn pest came from the same geographical area, either from Afghanistan or from neighboring Tajikistan, it would be advisable to concentrate on these countries when screening other accessions for Sunn pest resistance in the future, and to return for additional sampling.

The FIGS approach provides breeders with an efficient short cut to a best-bet list of promising accessions and should be routinely used when selecting screening candidates from genetic resource collections. FIGS has the potential to greatly reduce the resources required to mine genetic resource collections.

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Partners

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- Global Crop Diversity Trust
- Australian Winter Cereals Collection
- N.I. Vavilov Institute of Plant Industry, Russia

Stem rust Ug99: fast-tracking resistant varieties to vulnerable farmers

A seed multiplication crop of a stem rust-resistant variety of wheat at Melkassa research station in Ethiopia

Developing new wheat varieties resistant to Ug99

Overview

High-yielding bread and durum wheat varieties resistant to a potentially devastating new race of stem rust are rapidly emerging through an intensive international 'shuttle breeding' program. To avert disaster these are being fast-tracked to farmers in wheat-growing areas in the path of the air-borne rust spores.

Ug99 is an extremely destructive stem rust race that emerged in Uganda 10 years ago. From Uganda it spread to Kenya, Ethiopia, Sudan, Yemen and Iran, and it is now marching inexorably towards Central Asia, South Asia and possibly North Africa.

ICARDA, as part of the Borlaug Global Rust Initiative (BGRI) consortium working to prevent a Ug99 pandemic, is working to create new cultivars resistant to the fungus. Drawing on the priceless collection of wild and improved wheat in the ICARDA genebank and taking a 'shuttle breeding' approach, plant breeders are fast-tracking new varieties resistant to Ug99 and getting them rapidly to farmers in high risk areas.

ICARDA's genebank may hold the key

ICARDA holds a wide range of genetic variability in wheat in its genebank. Nearly all the wheat accessions are geo-referenced, characterized and available for crossing and exploitation in improvement programs. Scientists at ICARDA have extensively screened these wheat accessions – wild relatives of wheat, landraces and improved lines – for new sources of resistance to stem, yellow, and leaf rusts. Partners in stem rust hot spots in Ethiopia, Kenya and Yemen receive selections of wheat accessions to screen for resistance to Ug99 each year.

In 2008, at Tehama, in Yemen, 7000 bread wheat and 1000 durum wheat landraces were screened for resistance to Ug99, of which 111 spring bread wheats and more than 40% of the tested durum wheats showed resistance. These were sent to Njoro, Kenya, for further evaluation against variants of Ug99 that have overcome the resistance gene Sr24. Researchers found 45 accessions among the 111 spring bread wheats that were resistant, so these will be further evaluated.

At Debre Zeit, Ethiopia, researchers tested 238 wild wheat accessions against Ug99. The preliminary results showed that some of these wild wheat lines could be an important source of resistance to Ug99. The promising ones are now being crossed with elite bread and durum wheat.

Another interesting finding in 2008 was that fewer of the durum wheat materials tested in Yemen proved resistant to Ug99 compared with materials tested in Ethiopia and Kenya. This suggests that rust strains are probably more variable in Yemen and that lines that prove resistant are likely to prove resistant at other locations too. Because of this, Yemen could be an important location for testing lines for robust resistance to Ug99 in future.

Concurrently, genetic and genomic studies are underway on the most promising lines identified in Yemen and Ethiopia to characterize novel genes that give resistance to Ug99. These will then be transferred to breeding material. Scientists introduce these new sources of resistance from wild species, landraces, and improved varieties to produce new types of high-yielding wheat that have a combination of genes that give resistance to Ug99 and are adapted to local agroecosystems.

Shuttle breeding speeds up the race against Ug99

ICARDA's innovative approach to plant breeding combines elements of conventional breeding, decentralized breeding, participatory plant breeding, gene transfer and 'shuttle breeding'. Shuttle breeding is showing rapid results in the race against Ug99. This breeding strategy involves two successive plantings a year in different locations with different growing seasons. This cuts the time taken for resistance screening by half. Unlike most other shuttle breeding programs, ICARDA

ICARDA's approach to addressing Ug99 can be used to fast-track new varieties of other major crops to farmers to counter emerging threats

involves national research programs as 'shuttle partners.'

Crosses are made at ICARDA and sent to Ethiopia, Kenya and Yemen, for testing by national partners. The most resistant materials are sent back to ICARDA for further screening and then returned to the three countries for further exposure to the Ug99 fungus. In 2008, scientists in Ethiopia and Kenya screened 3825 lines and identified 1243 with resistance to Ug99. These will now be grown in further trials.

Getting Ug99-resistant seed to farmers

New resistant varieties cannot be disseminated without effective seed delivery systems. Recognizing this, ICARDA is helping government agencies and NGOs improve the distribution of seed. Seed of promising lines is multiplied early in the breeding program, so that supplies can be distributed as soon as the lines are officially released. In this way, farmers can get hold of improved varieties without delay.

Two durum wheat varieties resistant to Ug99, 'Bakalcha' and 'Malefia', have been released by the Ethiopian national program, developed from material supplied by ICARDA. These are already being multiplied on a large scale for wide distribution. ICARDA also supports the government-owned Ethiopian Seed Enterprise in producing, processing and distributing seed of the Ug99-resistant 'Barkumee' variety to state, private and small-scale farmers in the four major wheat-producing areas in Ethiopia.

Tracking the spread of Ug99

The growing prevalence of Ug99 in Ethiopia and its discovery in Yemen in 2006 led ICARDA to intensify efforts to track the spread of the fungus. In Yemen, to detect whether or not Ug99 was present in the main wheat-growing areas, researchers planted trap nurseries in the off-season. The trap nurseries could be a valuable early warning system for new virulent diseases such as Ug99.

Similar trap nurseries were planted in Njoro in Kenya, and Kulumsa in Ethiopia, and the seed multiplied in these nurseries was planted in the main crop season, July to November, to detect Ug99 in major wheat-production areas. Other nurseries were planted in West Asia, North Africa, South Asia, Central Asia and the Caucasus.

In October 2006, researchers detected a severe infection of Ug99 in Yemen that affected even the leading resistant varieties. Researchers supplied this information to the Ug99 global monitoring system set up by ICARDA, the International Maize and Wheat Improvement Center (CIMMYT), the US Department of Agriculture, and the UN Food and Agriculture Organization which is modeling the spread of the fungus using geographical information systems.

In CWANA, the extremely diverse wheat-production areas, mostly rainfed, are likely to become more susceptible to pest and disease outbreaks as a result of climate change. ICARDA's approach to addressing Ug99 can be used to fast-track new varieties of other major crops to farmers to counter emerging threats.

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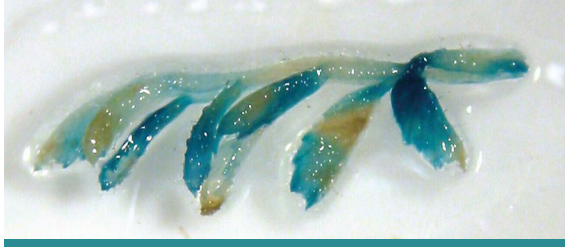
Partners

- Borlaug Global Rust Initiative
- International Maize and Wheat Improvement Center
- Ethiopian Institute of Agricultural Research
- Ethiopian Seed Enterprise
- Food and Agriculture Organization of the United Nations
- Agriculture Research and Extension Authority, Yemen
- Kenya Agricultural Research Institute
- United States Department of Agriculture
- International Fund for Agricultural Development
- Arab Fund for Economic and Social Development
- USAID
- Bill and Melinda Gates Foundation



It is now easy to see whether a particular gene has been incorporated using genetic transformation. The blue color is produced by an enzyme encoded by the marker gene that is linked to the drought-resistance gene researchers wanted to insert

The marker gene used in the plant on the right allows it to survive spraying with glufosinate ammonium herbicide, so it shows clearly that the gene of interest is also likely to have been inserted

Biotechnology produces better legumes faster

Overview

Until recently, legume crops have been improved purely using traditional breeding methods – which are relatively slow and expensive. However, ICARDA has made recent progress using newer molecular biology techniques with both chickpeas and lentils. These are two of the most internationally important food legumes, and many poor people around the world rely on them for protein in their diets.

Using modern techniques like molecular markers can speed up conventional legume breeding. ICARDA has successfully identified three such molecular markers, which are being used to detect resistance to Ascochyta blight, a devastating disease of chickpea. Researchers have also developed methods for genetic engineering in legumes, which introduce genes from more distantly related species – something that is impossible using conventional breeding methods.

Molecular markers help fight Ascochyta blight in chickpea

Legumes are particularly susceptible to diseases. For chickpea, Ascochyta blight disease, caused by the fungus *Ascochyta rabiei*, is a major constraint in cool and humid areas and can cause complete crop failure. Fungicides can be effective, but breeding resistant varieties is also effective, more environmentally friendly, and cheaper for subsistence farmers. Such breeding not only has to ensure that varieties have high enough levels of resistance to protect the crop, it also has to make sure that resistance will last for the commercial life of a variety. Long-lasting resistance is critical in the case of Ascochyta blight, because the fungus that causes it can evolve quickly – producing new strains ('pathotypes'). Indeed, ICARDA studies have recently shown that there are currently four pathotypes, I to IV, in order of increasing virulence. Thus plant breeders are in an ongoing 'race' with the disease, producing new varieties with resistance that is eventually overcome and so new forms of resistance are then required.

Efficient field and laboratory screening of breeding lines is necessary to ensure that resistance to Ascochyta blight is successfully incorporated into any new varieties. Field screening can be particularly difficult as disease conditions do not always develop properly in a given year, which means more breeding lines need to be tested in the following year. This can be an expensive process, so any method that shortens the period of screening can cut costs considerably. Thus, ICARDA now uses molecular markers to determine whether breeding lines developed by sexual crosses have had the genes for Ascochyta blight resistance successfully incorporated or not.

From a cross between chickpea lines FLIP98-1065 and ILC1929, which are resistant and susceptible to Ascochyta blight, respectively, 170 recombinant inbred lines (RILs) were produced. Researchers tested these RILs against Ascochyta blight using a scale of 1 to 9 (1 = disease-free, 9 = killed), and found significant differences among the RILs, under both plastic house and field conditions. Based on these disease-response results, DNA was pooled from five highly resistant and five highly susceptible RIL plants, to construct resistant and susceptible bulks.

Of the 100 SSR markers tested on the DNA of FLIP98-1065, ILC1929 and on the two bulks (resistant and susceptible), 10 showed differences between the parents and the bulks. Among these, three clearly differentiated the resistant and susceptible bulks, and QTL analyses confirmed their association with the genomic region conferring resistance to Ascochyta blight.

These three markers are now being used to select blight-resistant plants in early generations, such as F2, and also to tag resistance genotypes in advanced generations, such as F6. They will help researchers combine ('pyramid') a number of resistance genes from different sources in a new variety, and so make the disease resistance in new varieties much more difficult for Ascochyta blight to overcome.

Newly discovered markers will help researchers combine a number of resistance genes from different sources in a new variety

Genetic transformations show promise in chickpea and lentil

Agrobacterium tumefaciens is a species of bacteria that is the basis of the system most commonly used to modify many plant species genetically. It has the advantage of efficiently delivering large DNA segments into plants with few complicating chromosomal rearrangements and at low cost. Despite the difficulties in getting systems that work for legumes, ICARDA has developed *Agrobacterium* as a genetic transformation medium for lentils and chickpeas. These systems use the reporter gene *gusA*, which encodes the enzyme GUS (beta -glucuronidase). This reporter gene is linked to the gene of interest, such as drought tolerance, and GUS produces a blue color when successfully incorporated and expressed, thus indicating whether the gene of interest has also been incorporated and is being expressed.

This method was used with 10 chickpea lines. The rates of regeneration and transformation varied, indicating that success was highly dependent on the particular plant genotype; the two lines with the highest rates were FLIP86-5 and FLIP97-706.

A PCR test was used to show that the new gene was successfully introduced, by the positive amplification of the transferred gene with specific primers. Thus, researchers showed that various genes (the *BI-GST/GPX, DREB1A, LeTpx1*, *vst-1* and *chitinase* genes) were successfully introduced. So too was the marker *bar* gene which gives resistance to the herbicide glufosinate ammonium. The *bar* gene shows that insertion was successful by giving resistance to the otherwise toxic glufosinate ammonium, and indicating that the gene of interest is also likely to be successfully inserted, thus providing a rapid screening technique to speed up future breeding. The *bar* gene was stable from the first generation (T_0) through at least another five generations (T_5) of chickpea.

This *Agrobacterium*-mediated transformation technique enabled successful transformation of lentils with the genes *vst-1* (line ILL5582/T4) and *BI-GST* (lines ILL5883/T2 and ILL5588/T2). These two genes confer tolerance to the two important diseases caused by fungi: botrytis gray mold caused by *Botrytis cinerea* and fusarium wilt caused by *Fusarium oxysporum* f.sp. *lentis*, respectively. Additionally, lentil plants transformed with the *DREB1A* gene (line ILL5883/T3) were assessed for tolerance to drought and salt stress conditions. Compared to untransformed plants of the same genotypes, the transgenic plants survived on growth medium supplemented with polyethylene glycol (PEG) or salt (NaCl), which are early tests for tolerance to drought and salinity, respectively.

These successful transgene introductions are the first steps needed in finding novel ways to boost future legume varieties' tolerance to important diseases and environmental stresses such as salt and drought. Such tolerances are likely to increase in importance as the effects of climate change are felt.

Now it is necessary to further evaluate these breeding lines under simulated field conditions to ensure that the lines are robust under field conditions in the target environments. These tests will be done in a 'containment facility', which ICARDA is currently developing. The facility is a modern glasshouse that restricts any incoming and outgoing insects and pollen. This ensures that no transgene is released to the environment before repeated tests have assured complete safety.

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- Pulse Breeding - Australia
- University of Hannover, Germany
- Deutsche Sammlung von Mikroorganismen und Zellkulturen (German National Resource Center for Biological Material)
- CGIAR Generation Challenge Program
- European Commission

- Trials of cold-tolerant lentil varieties in Turkey produced lines for distribution to other countries for testing under different environments
- The release of disease-resistant lentil in India is the fruit of ICARDA's collaboration with Indian researchers

Lentil breeding helps farmers cope with harsh climates and disease

Overview

Since Neolithic times, people in Asia, Africa and southern Europe have cultivated lentil as a staple crop high in protein and micronutrients. Now, with the onset of climate change, lentil growers are facing new challenges. As temperatures rise and droughts increase, yields from traditional lentil varieties are dropping. Sowing at different times or in cooler locations is no solution as these varieties also cannot endure winter cold.

To help farmers cope with a changing climate, ICARDA has identified and bred varieties of lentil resistant to winter cold, summer heat, drought and disease. These varieties can produce high yields of lentil even in harsh conditions. Higher yields mean better food and nutritional security as well as income potential for farmers, as demonstrated by ICARDA projects distributing improved seed to local communities in India and Ethiopia.

Serving the developing world

Lentil (*Lens culinaris*) is a legume plant native to southwest Asia and northern Syria. Dried lentils are very nutritious, being high in protein, iron, calcium, phosphorus, zinc and B vitamins. As a result, lentil is an important staple across the developing world.

About three-quarters of the global lentil crop is grown and produced in developing countries. Reflecting this, lentil is one of ICARDA's 'mandate crops', and the focus of much research. ICARDA aims to improve the genetic stock of lentil, thereby serving the entire developing world with varieties resistant to disease and harsh environmental conditions.

Developing vigorous lentil lines

Lentil cultivation occurs mainly in the lowlands of temperate and Mediterranean environments and in tropical highlands. Traditionally, farmers grow lentils in the spring, making use of residual soil moisture and avoiding cold winter temperatures.

But local cultivars are very susceptible to drought and high temperatures, especially at the flowering and grain-filling stages of their growth cycle. Climate change is likely to make this even more of a problem. ICARDA is therefore identifying and breeding types of lentil that will help farmers cope.

Cold-tolerant lines

One way of dealing with the problems caused by drought and heat is to expand winter lentil cultivation in the cool highlands of Central and West Asia and North Africa. But to do this, lentil varieties are needed that are tolerant of cold conditions. ICARDA and the NARS of Turkey have therefore been evaluating genetic material at Hayamana research station, Turkey, where the temperature drops to minus 20^{o}C during severe winters.

ICARDA and the Turkish NARS identified lines that are tolerant of cold and used them in subsequent crosses. In 2008, the research team evaluated large numbers of breeding lines and third generation (F3) populations. Of this genetic material, many lines and single plants from the F3 populations survived the severe cold winter experienced in 2008. In collaboration with national programs, about 112 of ICARDA's germplasm and breeding lines tolerant to cold and suitable to different environments have been identified.

Drought-tolerant lines

Another way to deal with the effects of climate change is to develop lentil lines that can tolerate drought. ICARDA has approached this by collecting and characterizing 11,000 accessions of germplasm and breeding lines.

2008 was a very dry season in Syria and the Breda experimental station received only 152 mm of rainfall. These dry conditions were an ideal opportunity to identify germplasm tolerant of drought. Some promising lines yielded up to 778 kg of lentils per hectare, more than double the 330 kg per hectare

Lentil varieties developed by ICARDA are helping farmers maximize production, increase food security, and raise incomes all over the developing world

yield from the most productive small-seeded cultivars from Syria. ICARDA has distributed the drought-tolerant lines to national researchers around the world, in the form of packages of selected seed known as international nurseries and trials.

Heat-tolerant lines

In countries such as India, Bangladesh and Nepal, lentil crops can often be grown after another crop in one growing season. As global climate change takes hold and summer temperatures increase, farmers and researchers have been looking for an early-maturing variety of lentil that can tolerate heat and fit into a double cropping system.

In 2008, ICARDA assessed lentil lines selected from its driest experimental site at Breda. During the evaluation period (June to August), temperatures rose from 30^{O}C to 45^{O}C. Lentil lines that survived at temperatures above 40^{O}C at flowering and pod-setting stages were deemed heat tolerant.These will now be used in further crossing programs.

Improving livelihoods

Lentil varieties developed and improved by ICARDA are helping farmers maximize production, increase food security, and raise incomes all over the developing world. In particular, collaboration with the Indian Council of Agricultural Research (ICAR) and the Pulses and Oilseeds Research Station in West Bengal resulted in the release of a lentil variety called 'Moitree'. *Moitree* is a Bengali word meaning friendship, which reflects the fruitful partnership between ICARDA and Indian organizations.

The 'Moitree' variety has combined resistance against rust and *Stemphylium* blight, which had previously forced farmers in north east India to all but abandon lentil cultivation. Another advantage is that farmers can plant this variety late in the season after summer rice crops, potentially making use of 11 million hectares of otherwise fallow land. The ICARDA–India partnership has already distributed the variety to many farmers in West Bengal state.

ICARDA research on lentil has also benefited farmers in Ethiopia. The Ethiopian Institute of Agricultural Research (EIAR) collaborated with ICARDA in evaluating several Ethiopian landraces and introduced germplasm from ICARDA's collections. The researchers identified varieties resistant to both cold and disease (rust and *Fusarium* wilt). Lines released for commercial production have enabled farmers to grow lentils successfully in the cool Ethiopian highlands, where previously production was in decline. Funding from the Netherlands Government and the International Fund for Agricultural Development has enabled ICARDA and EIAR to further strengthen seed production.

By using the improved lentil varieties, coupled with ridge-and-furrow planting techniques, lentil growers have been able to harvest double or triple the national average for Ethiopia. And as lentil fetches a higher price than most other major food crops, many resource-poor farmers have been feeling the benefits. For example, some have replaced thatched roofs with corrugated tin, can afford to send their children to school, or have invested in cottage industries to process lentils on their own farms.

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Partners

- National Agricultural Research System, Turkey
- Indian Council of Agricultural Research
- Pulses and Oilseeds Research Station, Berhampore, India
- Ethiopian Institute of Agricultural Research
- The Government of the Netherlands
- International Fund for Agricultural Development
- Government of India

ICARDA's International Public Goods help food-legume farmers boost yields

- ICARDA chickpea cultivars resistant to Ascochyta blight boost farmers' yields and extend the growing season in the Ethiopian highlands
- New high-yielding faba bean cultivars resistant to root rot and water-logging, such as 'Walki', are expanding bean production in the central highlands of Ethiopia

Overview

Production of cool-season food legumes (faba bean, lentil, kabuli chickpea, field pea and grasspea) in problematic soils, mainly water-logged vertisols, is a common challenge in the Ethiopian highlands. In these areas, plants are often stressed by heat or drought at the end of the growing cycle, and diseases like wilt and root rots, Ascochyta blight, chocolate spot, rust, as well as terminal stresses are rife. The Ethiopian national agricultural research system has developed varieties with high yield potential, good resistance to key diseases and tolerance to water-logging suitable for early planting using traditional ridge-and-furrow planting systems. Most of these varieties were developed from ICARDA-supplied breeding materials, which have been developed and distributed around the world as International Public Goods (IPGs).

Parasitic weeds are another major constraint to faba bean and lentil production in many countries. Broomrape causes yield losses of up to 100% in a range of countries. And, possibly because of global warming, it is starting to appear in Ethiopia, too. Over 110 new lines are classified as highly resistant, and these give farmers good yields even under heavy infestations – when susceptible cultivars yield almost nothing.

Overcoming constraints to legume production

Cool-season food legumes (faba bean, lentil, kabuli chickpea, field pea and grasspea) are key commodities for small farmers in West and Central Asia and North and East Africa. They are major sources of food security and help maintain cereal production by improving soil fertility and reducing diseases and weeds in the following cereal crop. But in many countries productivity is very low because of the use of low-yielding varieties, problematic soils (acidity, salinity and water-logging), diseases and parasitic weeds.

ICARDA has played an important role in meeting this challenge by providing improved germplasm through its international nursery platforms and capacity building through on-the-job training for NARS researchers from national agricultural research systems (NARS). NARS researchers in both developing and developed countries have used this germplasm in their breeding programs or selected promising lines with high yields and disease resistance for release.

Adapting chickpea and lentil to the East African highlands

In the East African highlands, cool-season food legumes are adapted to vertisols that are often water-logged during the main rainy season. This means that farmers have to plant chickpea and lentil late in the season using the residual moisture left in soil, so exposing their crop to terminal drought, wilt/root rots, and rust infections. To overcome this problem, researchers at the Ethiopian Institute of Agricultural Research have bred lentil varieties with good levels of resistance to the key fungal diseases (rust and the wilt/root rot complex) that can be grown on water-logged vertisols.

Most farmers in the Ethiopian highlands normally grow desi chickpea on residual moisture. But with the advent of high-yielding Ascochyta blight and wilt/root rot resistant cultivars, the production of early-planted kabuli chickpea (which has larger seeds) is increasing. Farmers are now getting an average yield of more than 3 t/ha; they would need double the land area to get the same amount of tef (*Eragrostis tef*). Some early maturing chickpea varieties are also showing promise in double cropping systems with early-planted bread wheat or barley. This has the potential to increase the productivity of small plots of land in particular.

Breeding faba bean for disease resistance

Farmers trying to expand faba bean and field pea production on vertisols are confronted with root rot due to the stagnant water on their farms. This is a common problem in

There should be a real impact on the food and nutrition security of the rural and urban poor

the water-logged vertisols of the Ethiopian highlands. NARS researchers have released many high-yielding faba bean varieties through direct selection, and breeders have been able to transfer good levels of resistance from ICARDA germplasm to locally-adapted varieties. Among the faba bean varieties released with good levels of disease resistance are 'Moti' (ILB4432 x Kuse-2-27-33); 'Gebelcho' (ILB4726 x 'Tesfa'); Obsie (ILB4427 x CS20DK); and 'Walki' (ILB4615 x Bulga 70). The variety 'Walki' was developed for water-logged areas and is gaining in popularity in the central highlands of Ethiopia.

Bringing the benefits to far more farmers

Concerted efforts are being made by farmers' cooperatives, the farmers' union, public and private seed growers, and NGOs to multiply seed of cool-season food legumes for wide adoption. If this is successful, there should be a real impact on the food and nutrition security of the rural and urban poor and on income generation at both household and national levels. This is because these legumes bring a wide range of benefits, as studies have shown. Besides cash income, farmers can satisfy their household need for pulses. The increased income can help purchase agricultural inputs for cereals and pay school costs. Legumes also provide high-quality biomass for livestock feed. These high-yielding IPGs adapted to the highlands of Ethiopia could also benefit other countries with similar environments.

Broomrape resistance in faba bean

Broomrapes (*Orobanche crenata*, *O. aegyptiaca*, and *O. foetida*) are parasitic plants that tap into the roots of faba bean, and are found in Egypt, Morocco, Tunisia, Syria, Turkey, Portugal, Spain, and Sudan. They are starting to appear in new areas including Ethiopia, the second most important country after China in terms of faba bean production. Worryingly, global infestation with broomrape has doubled in the last eight years, mainly due to germplasm exchange and seed dispersal by the wind.

Host-plant resistance is the cheapest and most effective way of controlling the parasite. Broomrape resistance has been included in ICARDA's faba bean breeding program since 1997, and there are now about 1700 advanced lines with varying degrees of resistance. Studies at Tel Hadya have shown that under a heavy infestation by a mixture of broomrape species, increased pod and seed numbers can improve productivity and therefore be used to identify tolerance to the weed.

National research programs are testing the resistance, stability and adaptability of these lines. Such testing has identified eight lines which offer good stability under different broomrape-prone environments and which yield an average of 1800 kg/ha in heavily-infested soils, compared to 500 kg/ha for the susceptible check. However, in broomrape-free soils, the average yields of broomrape-tolerant lines are 15% less than the average susceptible checks. Breeding work is therefore continuing, in order to boost the yield potential of the tolerant lines.

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Partners

- Ethiopian Institute of Agricultural Research
- Institut National de la Recherche Agronomique de Tunisie
- Institut National de la Recherche Agronomique, Morocco
- General Commission for Scientific Agricultural Research, Syria
- Field Crop Research Institute of Egypt
- Institute for Public Policy Research, India
- Australian Centre for International Agricultural Research
- Department of Primary Industries, Australia
- Instituto de Investigación y Formación Agraria y Pesquera, Spain
- Consejo Superior de Investigaciones Científicas, Spain

- Participatory breeding shifts the selection process from the research station to the target environment
- Including farmers and researchers at the very early stages of selection helps in fitting the crop to different target environments and users' preferences

Farmer-focused barley research combats drought in Eritrea

Overview

Eritrea is one of the world's poorest countries, with a per capita GDP of just US$160. Cereals and food legumes, including barley – all of which are ICARDA mandate crops – make up most of the diet throughout the country.

A project designed to improve water productivity of food crops, focusing on participatory breeding, began in 2004. Rainfall in the area is very erratic and variable, averaging 500–700 mm. But in 2008, it was 128–132 mm – much less than the last 11 years' average. Rainfall variability from year to year – likely to increase with global warming – is a big problem in Eritrea and in many marginal areas worldwide, making it difficult to identify varieties with consistently superior performance. Even so, in 2008, new barley varieties were identified which out-yielded both local and improved varieties.

Agriculture in Eritrea

Eritrea's economy is based on subsistence agriculture, with over 80% of people depending on farming and livestock production. Traditional rainfed crop production accounts for 95% of total production. Barley, wheat, chickpea, lentil, and faba bean are the major crops of the highlands. A large proportion of the population is under-nourished, and almost 40% of children under five suffer from malnutrition.

The regional conflict and regular droughts and famines have caused major disruption, especially in rural areas. During the prolonged and very dry season, roughly from November to April, fields lie fallow for many months, ready for planting as soon as the rainy season starts. Rainfall averages 500–700 mm and is very erratic and variable, with most falling over a short period between June and August.

The country has a rich diversity of the most important crops. Diversity is also part of the farmers' culture, as a means of reducing the risk associated with such a vulnerable environment. They grow different cultivars of a variety of crops, landraces which are a mixture of different genotypes, and mix different crops, such as barley and wheat ('hanfets'). Such mixtures help them cope with the unpredictable rainfall, which is likely to become even more unpredictable with climate change: wet years favor the higher yield potential of wheat, dry years favor the better drought tolerance of barley. In addition, farmers prefer the bread (kitcha) made from the mixture.

ICARDA's early work in Eritrea

ICARDA began work in Eritrea shortly after independence in 1991 with a program of training, technical assistance and the provision of germplasm. By 1998, ICARDA was involved in barley breeding and participatory evaluation of barley landraces and, in 1999, joined a DANIDA project which looked at increasing barley production and participatory plant breeding.

This early work identified three promising cultivars: 'Shishai' for medium-altitude areas; 'Rhawa', released in Embaderho, northeast of Asmara; and 'Tekonda', released in Adi Keyh, a large barley growing area about 100 km south of Asmara and at around the same elevation (about 2400 meters above sea level).

Among the lessons learned from this early work, two stand out. In many villages, a few farmers explore what others are growing and what is available on the market, walking up to 40 km a day. They return with a few seeds that they plant on a small plot of good quality land. If the plants seem interesting, they are harvested and the seed tested by other farmers under different conditions. After repeated testing, the result may be a new variety. One of the leading wheat varieties in Eritrea may have originated in this way.

Another surprising result was that the research station is not a good place to evaluate and select barley lines. The 10 best lines in farmers' fields were among the poorest performers on-station, and the best lines on-station performed poorly in farmers' fields. The reason is that the research station used for barley

The improved germplasm and knowledge generated are international public goods that ICARDA will freely distribute to other NARS

screening is at the low end of barley's altitudinal range, which, like wheat, is a typical highland crop.

Participatory breeding of barley

Participatory breeding is the focus of a project implemented by ICARDA under the CGIAR Challenge Program on Water and Food, which aims to raise the water productivity (yield per unit of water used) of food crops like barley, wheat, hanfets, chickpea, lentil and faba bean. Italy provides additional funding.

During 2008, new barley varieties were identified that had a 4-year average yield higher than both local and improved varieties. In Adi Keyh, two varieties, 'Tsalta' and 'Seghem' out-yielded the local check by 33% and 36%, and the improved variety 'Tekonda' by 12% and 15%.

'Seghem' was the variety preferred by both farmers and breeders. In Wekerti, 40 km south of Asmara and with slightly higher rainfall than Adi Keyh, 'Yeha' and 'Tsaeda' produced on average over 800 kg/ha, 200 kg/ha more than the local check. As in Adi Keyh, there were large differences from year to year and from one farmer's field to the next, but even in the most stressed conditions, the local check variety was never the winner. Both farmers and breeders preferred 'Yeha'.

The project ends in 2009, but the Government of Italy's support which specifically targets the participatory approach, will allow the barley program, seed production of recently identified varieties, and the monitoring of their adoption, to continue. The improved germplasm and knowledge generated are international public goods that ICARDA will freely distribute to other NARS.

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Health benefits of barley-based foods

Improved barley varieties are gaining interest in developed countries for use in food products thought to provide health benefits beyond basic nutrition. This idea is based on the tocols (vitamin E) and beta-glucans (soluble fiber) found in barley. Barley landraces are still preferred by consumers for traditional dishes.

The seeds of over 500 barley landraces from 42 countries were grown at two locations, one favorable and one unfavorable. After harvesting, each landrace was assessed for quality characteristics of interest to specific food products. Of particular value is the beta-glucan content, since the renewed interest in barley centers around this dietary fiber and its effects on lowering blood cholesterol, blood pressure, and glycemic index. Researchers found that landraces from Eritrea, Palestine and Algeria had a high beta-glucan content and could contribute to the development of new food barley varieties.

Partners

- Danish International Development Agency
- National Agricultural Research Institute, Eritrea
- Hamelmalo College of Agriculture, Eritrea
- CGIAR Challenge Program on Water and Food
- Government of Italy

Community-based wheat seed production

ICARDA staff and villagers inspecting freshly-harvested wheat seed produced by a VBSE in Kunar province, Afghanistan

Improving seed systems and markets – from village to regional levels

Overview

Empowering communities and ensuring long-term sustainability are key factors in ICARDA's approach to village-based seed enterprises (VBSEs). ICARDA recently brought together a group of farmers from across the region involved in producing and marketing seed to their communities, to share their experiences with NARS partners. These farmers have one common ideal – to serve their communities and ensure access to quality seed of adapted varieties at the right time and at a reasonable price.

Seed regulations, particularly those concerning the movement of varieties and seed across national boundaries, can be a bottleneck to transnational plant breeding and dissemination programs. Harmonization of regulations helps bring tangible benefits for resource-poor farmers. A recent meeting agreed to the harmonization of regulations across the Economic Cooperation Organization (ECO) region. As a direct result of this and the felt need for a regional association to translate policy into reality, a new regional seed association has been formed.

Run by farmers, for farmers: village-based seed enterprises

VBSEs are farmer-based seed production and marketing units, owned and managed by farmers. They aim to produce quality seed of the locally-adapted varieties that farmers prefer, enabling them to take control of their own seed business.

Each VBSE is made up of a group of 10 to 15 progressive farmers. ICARDA provides an initial seed stock of the best locally-adapted improved varieties of staple crops, together with other inputs, including seed cleaners, technical assistance and training. The VBSEs then produce and market quality seed directly to other farmers, government agencies, NGOs and other groups.

ICARDA has shown that VBSEs are economically viable. For example, during the 2006–07 winter and spring seasons, the 15 VBSEs in Afghanistan earned a net profit of US$315,531 whereas by 2007–08, it had risen to over US$1.3 million for the 17 VBSEs.

VBSEs are making a real impact in Afghanistan through sustainable seed operations, and are expected to meet the country's large supply-demand gap for quality seed. It's now time to share this success with farmers in other parts of the region.

Learning from one another: farmer seed entrepreneurs share their experiences

In February 2008, ICARDA brought together farmers with experience of farmer-based seed enterprises from around the region to meet with NARS counterparts from Afghanistan, Algeria, Egypt, Eritrea, Morocco, Oman, Pakistan, Syria and Tunisia, as well as technical experts from FAO and ICARDA. Participants included individual farmers from Algeria, Morocco and Tunisia, representatives of VBSE members in Afghanistan and Egypt, and of cooperatives in Yemen and NARS scientists.

During the discussions, a VBSE member from Afghanistan commented *"ICARDA has changed our lives and that of our communities by introducing new approaches and technologies. Today we are proud producers and suppliers of quality seed in our district and beyond."* And an entrepreneur from Algeria said, *"The [seed] business is highly profitable and now I am starting to build the infrastructures and expand my activities with the benefits".*

Evidence shows that VBSEs are technically feasible, economically profitable and sustainable in the long term if properly designed, implemented and linked to partner institutions. Participants concluded that the key factors for success are diversifying crops, gaining access to seed of improved varieties and to credit facilities, capacity development in marketing, and enabling institutional arrangements for private sector investment. All agreed that VBSEs work in niche markets and complement rather than compete with the formal seed sector.

Evidence shows that village-based seed enterprises are technically feasible, economically profitable and sustainable in the long term

Moving closer: integrating national seed programs

Harmonization of seed regulations between countries is important in stimulating agricultural development and economic growth by creating regional seed markets that attract foreign and domestic investment.

The member countries of the Economic Cooperation Organization (ECO) – Afghanistan, Azerbaijan, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkey, Turkmenistan, and Uzbekistan – were given a grant from FAO's Technical Cooperation Programme to help strengthen seed supply in the region. ICARDA worked with FAO and the ECO Secretariat to implement the project. These countries have many features in common and could establish a regional seed market linked to the global seed industry. But, harmonization of regulations, especially related to variety release mechanisms, seed certification schemes and phytosanitary measures, and the creation of a regional mechanism to achieve this are vital to the success of any regional initiative.

Over 50 senior government officials from ECO countries, representing national variety release, seed certification and plant quarantine offices, attended the final workshop in a series on regional harmonization held in Istanbul, Turkey, in July 2008. Delegates unanimously endorsed the creation of a legal mechanism to ensure the harmonization of seed regulatory frameworks in the region under the umbrella of the ECO Secretariat.

New regional seed association to create regional seed market

ECO, FAO and ICARDA worked closely with member countries, and particularly the Government of Turkey in facilitating the meeting, which led to the formation of the new regional seed association, which will be based in Ankara, Turkey.

The main purpose of the association is to create a forum for public-private partnership in the seed trade. Membership will be open to all seed companies and service providers to the industry from the ECO region and beyond. The association will represent the interests of the seed industry and facilitate dialogue with government to put in place a policy and regulatory framework for the development of a competitive seed sector.

ECO member countries collectively represent a huge seed market worth billions of dollars. The estimated domestic annual seed market based on potential demand in the top three countries alone is close to US$1 billion.

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Partners

- Ministry of Agriculture and Irrigation, Afghanistan
- Economic Cooperation Organization member countries: Afghanistan, Azerbaijan, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkey, Turkmenistan, and Uzbekistan
- Economic Cooperation Organization Secretariat
- Development Alternatives, Inc., United States of America
- Unites States Agency for International Development
- Japan International Cooperation Agency
- Food and Agriculture Organization of the United Nations

The conference provided the farmers with a platform to show some of their local bread and to tell how and why it is like it is

Researchers gain new insights into the breadth of farmers' knowledge and their day-to-day concerns

Storytelling unlocks rich farmer knowledge

Overview

Farmers have a rich store of knowledge, passed down through generations and gleaned from experience. Tapping into this knowledge, and helping researchers understand how important it is a vital element in the spread of participatory research methods involving farmers.

ICARDA's new strategy for sharing knowledge between researchers and farmers has made an exciting breakthrough. At a 'conference with a difference', researchers invited farmers to take the stage and share their experiences in the way they know best, by telling their stories.

As a result, farmers, comfortable with the tradition of storytelling, shared a rich store of knowledge and real-life experiences. Researchers gained a deeper understanding of the contexts the farmers work in and the problems they want help with. This innovative way of sharing knowledge to improve interaction between scientists and farmers can be applied widely.

Understanding how farmers share knowledge

Researchers and farmers live and work in different worlds. But, for research to be of real use to farmers, one thing that's essential is for researchers to understand farmers, and how they live and work. Although this is widely acknowledged, few research organizations have successfully overcome the barriers to communication between scientists and farmers.

Many of the obstacles to communication are cultural. Scientists on the one hand live in a world of technical language, formal processes for research and research communication, and the written word. Farmers on the other hand are comfortable learning informally, by seeing and doing, and hearing about other farmers' experiences.

Rural communities have a rich aural heritage, passed down through the generations and from village to village by stories and anecdotes. This is still the way farmers prefer to get and receive information, even though nowadays it is often by mobile phone as well as face-to-face. They do not appreciate written material or look at the internet - not only because some farmers cannot read, but also because even those that do read often just prefer finding out from others.

ICARDA barley researchers used this analysis of how farmers prefer to give and receive information to arrange for farmers to share their experiences through telling stories. They invited over 50 male and female farmers from Algeria, Egypt, Eritrea, France, Iran, Jordan and Syria to a storytelling conference.

Doing it the farmers' way

ICARDA made sure that the farmers would feel at ease when telling their stories. In villages it's customary for all to gather round to hear stories and the arrangements for storytelling at the conference followed this tradition. Requests for stories were not prescriptive. Farmers could tell their stories in the way they preferred and share what was important to them. This format meant that farmers could talk about issues and feelings that are often considered too trivial to be addressed at formal conferences or not even relevant.

Some farmers, especially the women, were a little shy in telling their stories at first. But, once the conference got under way, farmers realized that others valued hearing about their experiences and they gained confidence and enthusiasm. They told how their farms have changed, how markets have changed, how the crop varieties they grow have changed, and how their living standards have changed. Some of the stories included tales of their experiences with crop trials in the ICARDA Participatory Plant Breeding Program.

A highlight of the conference was a show-and-tell 'food fair'. Farmers showed their bread, food products and crop varieties, and related how these have evolved to meet local tastes and cultural preferences.

This facilitated knowledge-sharing and was a runaway success

This facilitated knowledge-sharing and was a runaway success.

Researchers were fascinated by the stories told by farmers. They deepened their understanding of the problems farmers face. Their appreciation of the nature and scope of farmers' knowledge and experience of local conditions grew. They went away thinking about how to use this new knowledge in planning research to best help farmers.

Forging links farmer-to-farmer and between farmers and researchers

ICARDA also took advantage of the conference to launch other innovative ways to share knowledge. Farmers often see ICARDA and other research organizations as communication hubs through which all information flows. They do not appreciate the value of networking with other farmers or of talking to researchers directly.

To change this, the conference organizers encouraged the farmers who attended the conference, to locate themselves on a map of the world and add links to other farmers and researchers as the conference progressed. Farmers soon began to see that by linking to other participants – farmers and researchers – they could tap into a considerable web of knowledge and experience and share theirs much more widely.

Exploiting the mobile phone revolution

Throughout the developing world there is a boom in the use of mobile phones. They are relatively cheap and user-friendly. Nearly everyone can hear and speak, even though they may not be able to read or write. It's true that not everyone in rural areas has a mobile phone or access to one. But it's surprising just how many do – over 70% of farmers at the conference said they either had a mobile phone or could use one that belonged to someone else. In many countries, mobile phone applications are leapfrogging computing and the internet.

ICARDA has integrated the tradition of storytelling with mobile phone technology and shown farmers how to make short video clips of stories that they could send by mobile phone. In this way, farmers could share their stories and the stories of other participants with friends and neighbors when they returned home. Plus, the video clips, recordings and translations of transcripts of the stories have been put on the conference website so that they can be shared even more widely.

A knowledge-sharing triumph

All in all, the conference, part of a pilot project in the CGIAR Information Communication Technology and Knowledge Management (ICT-KM) Program, was a huge triumph. The UK Department for International Development featured the conference as a Research for Development (R4D) online case study and as a story in the *New Agriculturalist* magazine.

ICARDA is now examining other innovative strategies to improve communication between researchers and farmers. These include radio programs, training videos and databases – marking an important breakthrough in better directing research to farmers needs.

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Partners

- CGIAR Knowledge Sharing Project
- Centre for Sustainable Development and Environment, Iran
- National Center for Agricultural Research and Extension, Jordan

Farmers benefit from improved irrigation techniques in the Nile Delta

- Raised bed systems like this in Egypt can cut water use by 30%, and fertilizer use and labor costs by 35%
- Field trials showed that deficit irrigation and better irrigation scheduling can significantly improve water productivity

Overview

Agriculture is a thirsty business, using more than 75% of water supplies in the driest countries of Africa and Asia. In Egypt, agriculture receives the lion's share of water, amounting to nearly 90% of the available water resources. Here, finding new efficient ways to irrigate fields is crucial for dealing with water scarcity, especially in the face of rising populations and climate change. Changing attitudes is just as important: any technique developed through research is worthless if farmers do not use it on their own land.

ICARDA's Irrigation Benchmark Project, sited in Egypt, was a community-based venture that involved farmers directly in developing, testing and implementing new irrigation options. The research showed that water-saving irrigation techniques on raised bed systems substantially reduced water application without any appreciable loss in crop yields. And where farmers opted for high-value crops, incomes increased, thereby securing livelihoods and combating poverty.

Involving farmers in research

ICARDA's Irrigation Benchmark Project, one of the three Water Benchmark Projects located in West Asia and North Africa, placed great emphasis on community participation. The other two benchmarks addressing rainfed and dry rangelands are located in Morocco and Jordan respectively. The first four-year phase of the project in Egypt, which ended in 2008, tested new growing systems at three sites in the old, marginal and new lands in the Nile Delta. At these sites, farmers, national and international specialists, water-users' associations, other community groups and researchers worked together to design and implement on-farm trials of irrigation techniques, agronomic practices and improved technologies.

The trials were conducted in fertile and salt-affected fields on various farmers' holdings. The team tested improved growing technologies on crops including rice, wheat, corn, faba bean, groundnut, berseem and cotton.

Because of the challenge of water scarcity in Egypt and the need to further improve agricultural production with less water, and since the Irrigation Benchmark project addresses these issues, governmental organizations also took part in the project. In particular, the Extension Services of the Ministry of Agriculture were involved in disseminating the tested technologies through field demonstrations, farmer schools, farmer field days and traveling workshops.

Getting more crop per drop

One of the main approaches tested in the Irrigation Benchmark Project was deficit irrigation. The rationale behind this approach is to cut down the amount of water applied, accepting a slight reduction in crop yield. In other words, the aim is to sacrifice a small amount of yield per unit of land to achieve a higher yield per unit of water applied, or 'more crop per drop'. Agricultural scientists developed this approach recognizing that, in dry areas, irrigation water is the more precious commodity and that any water saved can be used to irrigate other fields, thereby expanding the production.

The ICARDA research team tested several irrigation techniques. It demonstrated that options such as drip and sprinkler system irrigation can produce greater crop yields per unit of water than conventional surface irrigation and lead to water savings of 3–22% compared with traditional furrow systems.

The Irrigation Benchmark Project also introduced to farmers the raised bed system, which incorporates larger crop strips and fewer furrows than conventional field systems.

Using a raised bed system automatically reduces the amount of water used in irrigation as there are fewer furrows conveying water within the field. In the ICARDA trials, farmers planted crops on raised beds 1–1.5 meters wide. The number of furrows in this system was half that of conventional fields

By growing profitable crops in a raised bed system…farmers increased their net income by more than 30%

in the Nile Delta and farmers consumed 30% less water. Labor costs for preparing land, irrigating and controlling weeds also dropped by 35%, and fertilizer application was reduced by 35%.

The net return of wheat grain yield per unit of water was 20% higher than that from conventional furrow irrigation. But perhaps most impressively, crop yields from the raised bed system did not suffer at all, but were the same or even higher than those from conventional fields.

Another aspect of the Irrigation Benchmark Project was to develop computer simulation models to help with irrigation scheduling. Even small amounts of water applied at the most sensitive stages of crop growth can make a big difference in alleviating moisture stress.

The CROPWAT decision support model developed by FAO was calibrated and validated to help identify key timings for farmers to irrigate and save water with almost no reduction in crop yield. It was used for irrigation scheduling scenarios at two Project sites (El-Bustan, a new land site and El-Monofia, an old land site). For wheat production at El-Bustan, the model predicted that sowing during the first half of November could save about 8% of the applied irrigation water with only a 5% yield reduction. Extension specialists can use such models to help farmers make the best decisions depending on their farming needs.

Securing livelihoods

As well as 'crop per drop', the ICARDA project team in Egypt also looked at 'profit per drop'. It considered the crops grown on irrigated land and encouraged farmers to grow profitable crops such as wheat and maize on old land and wheat and groundnuts on the new lands. Data from the raised bed technology introduced on the old land showed that, for wheat, farmers can obtain an additional net return of 566 Egyptian Pounds (E.L.) (US$ 106) per hectare or 0.96 E.L. (US$ 0.18) per cubic meter of water use. By growing profitable crops in a raised bed system, and reducing the costs associated with employing farm labor and pumping irrigation water, farmers increased their net income by more than 30%.

By working closely with farmers and community groups, the Irrigation Benchmark Project has taken important steps in closing the gap between irrigation technology and practice. The project has taken the proven technologies and practices to development projects and, through extension services, to other farming communities in the Nile Delta for demonstration and adoption. Several thousand farmers have already adopted many of the project outputs. This is critical if the limited water and land resources of Egypt are to provide food for the country's population that is projected to increase from the current 83 million to more than 100 million by the year 2025.

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Partners

- Agricultural Research Centre of the Ministry of Agriculture, Egypt
- Extension Service of the Ministry of Agriculture, Egypt
- National Water Management Centre of the Ministry of Water and Irrigation, Egypt
- Local communities in El Minufieh, El Sarw and El Bustan, Nile Delta, Egypt
- International Fund for Agricultural Development
- Arab Fund for Economic and Social Development
- OPEC Fund for International Development

Mulching alternate furrows instead of all (as shown here), helps cotton plants thrive and frees up more wheat straw for feeding to animals

The combination of mulching and irrigation using moderately saline water had a marked impact on both cotton yields per hectare and cotton yields per unit of water (water productivity)

Sustainable use of salty water for irrigation in Uzbekistan

Overview

Freshwater is in short supply in a growing number of countries in Africa and Asia, and what is available cannot meet the demands of agriculture, industry and households. To cope with this shortage, some farmers are using saline water to irrigate their crops. But this can bring problems of another kind, because as water evaporates from the soil surface during hot summers, salts can build up around the plant root zone and reduce crop yields.

Farmers should use saline water for irrigation only if they also take steps to mitigate potential salinity problems. ICARDA and its partners investigated how spreading wheat straw over fields can reduce such problems in a cotton-growing area of Uzbekistan. Results were encouraging. Firstly, mulching with wheat straw improved soil quality and increased crop yield. Secondly, the amount of mulch applied per hectare was relatively low, freeing up large quantities of wheat straw to feed livestock.

Filling an information gap

More than 20% of the world's irrigated land is already salt-affected and/or irrigated with saline water. And as populations grow and demand rises for food, feed, fiber and energy, larger areas of salt-affected soils will need to be cropped in the future. These soils are a valuable resource that cannot be neglected or abandoned, especially in areas where a lot of money has already been invested in irrigation infrastructure.

In Central Asia, most farmers make a living from growing cotton during the summer months. High temperatures, high evaporation rates and low rainfall at this time of year mean that 80% of arable land in cotton-producing countries is irrigated. But supplies of freshwater are dwindling. As an alternative, some farmers are using saline water to irrigate cotton. However, using saline water for irrigation without appropriate management can trigger the accumulation of salts in the root zone and reduce crop productivity. Although farmers recognize that mulching could help overcome potential problems of salt build-up associated with saline irrigation, little research data exists on the subject.

To address this information gap, ICARDA, in partnership with the International Water Management Institute (IWMI) and the Uzbek Cotton Growing Research Institute, carried out a three-year study to assess the effects of mulching cotton fields with wheat straw.

The study took place in the Syr-Darya River Basin of Uzbekistan, a leading world exporter of cotton. In this basin, the problem of salt-affected soils has increased dramatically as a result of large-scale irrigation. In fact, the area of salt-affected soils there rose from 0.34 million hectares to 0.61 million hectares (an increase of almost 80%) in just one decade (from 1990 and 2000).

Crop residues placed on the soil surface as mulch can shade the soil, and serve as a barrier which prevents water evaporating from the soil. The practice also slows surface run-off and increases infiltration of water through the soil. The research team therefore evaluated how these benefits affected soil quality and cotton productivity. The team also looked at the impact of irrigating with water of differing qualities: moderately saline water (2600 mg salt per liter), highly saline water (5300 mg salt per liter) and a blend of equal volumes. These treatments were applied with and without mulching using wheat straw applied at a rate of 1.5 tons per hectare on alternate furrows.

Improving soil quality and raising cotton yields

Results from the field study, completed in 2008, showed a clear improvement in soil quality when furrows were mulched with wheat straw. The average increase in soil salinity on mulched plots was just 9% over baseline values, compared with 20% on non-mulched plots.

In all three salinity-level treatments, mulching increased both cotton yield per hectare of land and cotton

Restricted use of straw mulches, combined with irrigation using moderately saline water, offers real benefits to cotton growing farmers

yield per unit of water (or 'water productivity'). On average, cotton yield and water productivity were 7% and 6% higher respectively on mulched plots than on non-mulched plots.

Mulching was most effective when combined with irrigation using moderately saline water. In this scenario, cotton yield without mulch was 2.04 tons per hectare, but with mulch was 2.28 tons per hectare: an increase of 12%. And water productivity rose from 0.80 kg cotton per cubic meter of water without mulch to 0.91 kg cotton per cubic meter of water with mulch, an increase of 14%.

The increase in cotton yield in the mulching treatments was due to less water being lost through evaporation from the soil surface, better storage of moisture, and management of soil salinity within the acceptable limits. The water stored in the soil as a result of mulching was used in the transpiration process and contributed to the increase in crop water productivity.

With regard to the effects of water salinity, both yield and water productivity fell as salinity increased, whether or not the soil was mulched. For example, yields were 2.28, 2.02, and 1.84 tons per hectare for the moderately saline, blended, and highly saline water, respectively, in mulched plots. For the same treatments, water productivity followed the same downward trend: 0.91, 0.80, and 0.75 kg cotton per cubic meter of water.

Freeing up straw for other farm uses

The research team achieved increases in crop yield per hectare of land and per unit of water by applying straw mulch on alternate furrows only. This meant that the application density was just 1.5 tons per hectare of farmland, compared with 8–10 tons per hectare in conventional practices. Although mulching with wheat straw at higher densities than those used in the field study would produce even higher cotton yields, it would also reduce the amount of wheat straw available for feeding livestock.

Distributing the benefits of wheat straw between different activities on the farm is essential for maintaining agricultural diversity and livelihood security in the face of economic and climate change. In this study, reducing mulching densities actually freed up 80% of the wheat straw for other uses.

With regard to cotton, the research project result of a 12% increase in yield per field suggests that restricted use of the straw mulches, combined with irrigation using moderately saline water, offers real benefits to farmers. These results have been shared with Uzbek farmers through farmers' fairs and field days. Using these tested holistic techniques, cotton-growing enterprises in Uzbekistan and other countries in Central Asia can be profitable even when freshwater is in short supply and future climates are uncertain.

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Overgrazing of rangeland like this was a problem tackled in 2008 using community-developed rangeland resting plans

Grasses and other vegetation are able to regenerate on protected rangeland but remain sparse on sites that are continuously grazed

The grass is greener on rested land in Tunisia

Overview

The extensive rangelands of North Africa and West Asia were traditionally used by nomadic herders who moved their livestock from one grazing ground to another in a seasonal cycle. But now almost all rangelands in arid areas are grazed continuously. This has severely degraded rangeland soils and led to a decline in grass species palatable to livestock.

In Tunisia, 4 million hectares of land is open rangeland used for grazing sheep, goats and camels. To help farmers manage communal rangelands more sustainably, ICARDA established a community based organization in southern Tunisia. This organization reinstated 'resting' as a way of restoring the fertility and biodiversity of Tunisian rangelands. ICARDA researchers monitored the effects of this resting and found that it increased the number and productivity of perennial species such as grasses, even during drought years.

Creating community-development and rangeland-resting plans

Southern Tunisia, which forms part of the Sahara desert, is a fragile, arid landscape. Rainfall is less than 200 mm a year and drought is increasingly common. Traditionally, pastoral communities migrated seasonally across this land, moving their livestock from one rangeland to another. Now, most local people have abandoned nomadic lifestyles and have instead formed settled farming communities. As a result, almost all rangelands in arid areas in Tunisia are now grazed continuously with no restrictions on stocking rates.

Overgrazing in Tunisian rangelands has caused a number of problems. It has reduced the fertility of soils and led to a decline in perennial plant cover, threatening the existence of grass species important to grazing animals. Global climate change is adding to these threats by increasing the frequency of droughts in the region.

To formulate a local solution to rangeland problems, ICARDA worked with an agropastoral community in southern Tunisia to develop a community development plan. This initiative took place within the framework of the Mashreq–Maghreb III project and the Agropastoral Development and Promotion of Local Initiatives in Southern Tunisia (PRODESUD) project funded by the International Fund for Agricultural Development (IFAD). A key achievement of the plan was the creation of the Agricultural Development Group, a community based organization, to encourage the efficient management of communal farming resources.

Under the leadership of the Agricultural Development Group, local farmers implemented a short-term resting program on around 4000 hectares of collective rangelands. ICARDA researchers monitored the effects of this resting program between 2006 and 2008.

Conserving rangeland biodiversity

The researchers looked at the proportions of vegetation cover and number of plant species on the study sites. They compared protected sites with those that were continuously grazed. The team found that total plant cover increased as a result of resting: it was around 52% on protected sites compared with 38% on open sites in 2006, and around 47% and 16% respectively in 2008.

Rainfall was very low in 2008, which accounts for the lower plant cover on both open and protected sites in this year compared with 2006. However, the figures for perennial plant cover tell a different story. Although perennial plant cover on open sites was lower in the drought year of 2008 than in 2006 (7% compared with 14%), on the sites that had been protected for two years, it was significantly higher (39% compared with 31%). These figures demonstrate that the effect of resting on perennial plants is amplified in dry years, when annual species are less dominant.

On the study sites, resting clearly helped rangeland recover its fertility and yield a higher degree of plant

An overall increase in forage vegetation means that farmers can reduce their dependency on bought-in animal feed

cover. Another positive effect was that species richness increased on rested sites for both total plant species and perennial species. Again, the increase was more pronounced for perennial species, including perennial grasses, during the drought year of 2008, when annual species were less dominant. Indeed, the number of annual species was comparable on both open and protected sites, indicating that annuals depend more on rainfall than on any one method of management.

The perennial grasses that thrived on protected study sites included *Stipa lagascae, Pennisetum dichotomum* and *Stipagrostis plumosa*. The scarcity of these grasses on open areas confirms their weak resistance to continuous and heavy grazing. It also emphasizes the need to allow land to rest so that grasses can regenerate and biodiversity can be conserved.

Increasing animal forage

The ICARDA team found that allowing land to rest increased the biomass productivity of the rangeland study sites. In 2006, biomass productivity was 800 kg of dry matter per hectare on protected sites compared with 450 kg of dry matter per hectare on open sites. In 2008, after a two-year rest period, biomass productivity on the protected sites had increased by around 160% to 2135 kg of dry matter per hectare. In contrast, on open sites that had been freely grazed, biomass productivity had dropped to just 236 kg of dry matter per hectare.

The increase in biomass on rested sites was due to vigorous growth of existing species and the regeneration of degraded or even disappearing palatable grass species. The result is an overall increase in forage biomass, which means that farmers can reduce their dependency on bought-in animal feed.

Improving farming techniques

The ICARDA research shows that resting rangeland provides several benefits: it improves soil quality and rangeland productivity, thereby conserving biodiversity and natural resources; it increases amounts of available forage, reducing the need for farmers to buy in supplementary feeds; and it is a useful tool for mitigating the effects of drought, which is becoming more common due to global climate change. As a result, the technique is being adopted not just by communities in the PRODESUD project area (14 sites covering more than 45,000 hectares) but also in other areas of southern Tunisia such as communal rangelands at Mahmouda where 50,000 hectares are already being rested.

The resting technique is fit for use in other rangelands, in Tunisia and elsewhere, which meet certain criteria: the land should contain relics of important range species and the soil should be covered by a wind veil (a deposition of topsoil or sand caused by wind action) which prevents moisture loss and allows seeds to germinate. The technique is not suitable for extremely degraded rangelands, where seed stocks are lacking and/or the soil is superficial. In these situations, techniques that directly conserve and improve soil and water – such as water harvesting techniques like contour ridging – are more appropriate.

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Growing crops in plastic houses means more household income from less water on marginal lands

'Cham-6' was the best performing of all improved wheat varieties introduced by the project

Fighting poverty, improving food security in Balochistan

Overview

Balochistan is the largest and poorest province in Pakistan. With degraded land, frequent drought, and few economic opportunities, rural poverty remains above 70%. ICARDA's work with national institutions has shown how to address these problems, using innovative methods and an integrated grassroots approach. ICARDA led the applied research component of a USAID project that recently concluded its pilot phase.

Major activities covered by the project were water resources management, protected agriculture, rangeland rehabilitation, improved animal husbandry, and new plant varieties. Women's role in agriculture, priority areas for value-added agriculture and capacity development were also included.

The project aimed to keep policy makers aware of all these activities and contributed to their scaling up. It has successfully worked with farmers to introduce technological innovations that have clearly had a positive impact on family incomes and rural livelihoods.

Managing scarce water

Water loss was cut by building water regulation structures, leveling farmers' fields, lining irrigation water courses, and improving stock water ponds. Irrigation water productivity was boosted by introducing soil amendments, drought- and cold-tolerant varieties, high-value crops (e.g. fruit trees), and protected agriculture.

Low-cost water regulation structures, developed with full community participation, and the leveling of farmers' fields together increased harvested water by 67% and saved 16% of irrigation time. Lining of water courses reduced irrigation water losses by 79–100%. Improvement of ponds increased water availability by 44% and by 50% of the original storage.

Water harvesting together with other sources of irrigation water helped stabilize the traditional *Sailaba* (floodwater) farming system. Applied cropping technologies (mechanical seed drilling, use of inoculums, and soil amendments with fertilizers) substantially improved water productivity.

ICARDA provided drought-tolerant varieties of almond, pistachio, and olive for use by farmers. Grapes (*Vitis vinifera*) and pomegranate (*Punica granatum*) were planted at the Quetta research center for germplasm maintenance and propagation. The survival rates of the introduced fruit trees were moderate to high.

Controlling the environment for high-value crops

Protected agriculture (PA) technology (plastic houses) opened farmers' eyes to the economic benefits of planting high-value crops (vegetables and spices) for local markets with limited water on marginal lands. Farmers learned basic PA techniques, such as preparation of terraces, regulation of heating, and 'fertigation'.

At the end of the first year the impact of PA was clear. The net return from cucumbers under PA was US$117 in one community, compared with US$12 from wheat in open fields using the same amount of water. The net return per cubic meter of water under PA was US$3.31. The internal rate of return was 27%. Sensitivity analysis using different electricity rates, water charges and market prices confirmed the economic feasibility of PA.

Breathing new life into degraded rangelands

Biomass production, grazing capacity and diversity of vegetation were monitored during 2006 and 2007 at a protected site and in open areas. In 2006, forage production at the protected site was twice that of the open areas. In open areas, forage production was low, not exceeding 31% of that at the protected site. One hundred and fifty animals, owned by 10 households, grazed the protected site during the winters of 2007 and 2008. Community members themselves decided on the timing and interval of grazing.

Water-harvesting micro-catchments are simple pits or furrows that trap run-off water, and channel it to

Innovations have clearly had a positive impact on family incomes and rural livelihoods

specially planted fodder shrubs. This results in better nutrition for animals, higher profits for farmers, and less erosion from uncontrolled run-off. Micro-catchments were developed on a 15-hectare site. Two years later, shrub survival rates are 70 to 90% and soil loss has been significantly reduced. Community members are managing the established fodder shrubs.

The project established shrub nurseries at Quetta and Siddigabad to multiply planting material of exotic species from ICARDA, and to train field staff and community members on how to set up and manage fodder nurseries. A total of 1157 different seedlings of native and exotic species were planted.

Keeping animals healthy

A study at Siddigabad with farmers' flocks compared the effects of treating diseased animals, providing vaccinations and de-worming treatments, or doing neither. Those animals given no treatment or preventative measures gained less weight, had lower value skins, fewer lambs and lower value wool. The participatory approach enhanced farmers' awareness of animal health issues, their skills in vaccination and de-worming, and their ability to treat common ailments.

Another trial showed the value of feeding concentrate during the breeding season, pre-lambing/kidding, and post-lambing/kidding. Animals fed concentrate had higher conception rates and lambing/kidding percentages than the control. The mortality of lambs/kids and incidence of abortion were also reduced.

Fattening trials showed how profitability of lambs could be improved. The average increase in profit generated from fattening was about US$10 per lamb.

Improving staple varieties

Farmers were supplied with seed of improved varieties (drought and cold tolerant) of wheat, barley, lentil and vetch to test over multiple cropping seasons under a range of environmental conditions.

During the second growing season, the new wheat varieties had higher grain yields than the local wheat, with 'Cham-6' being the best performer (1.7–2.9 t/ha). The improved varieties 'AZ/WW' (1.9–2.2 t/ha) and 'Soorab-96' produced the highest grain yields among the barley varieties.

This is the first time that lentil has been introduced in Qilla Saifullah and Loralai districts. Yields of 'Shiraz-96' were the highest. Farmers were pleased with the performance of the lentil varieties under the severe cold and dry conditions. ILL-8081 and 'Shiraz-96' were preferred due to their red color and medium grain size.
ICARDA, in collaboration with local scientists, started up informal seed production by adopting the village-based seed enterprise approach. Production proved economically feasible, if the premium prices paid for quality seed could be maintained.

Training women

Rapid rural appraisal found that women and children play important parts in livestock feeding activities (grazing, cutting and feeding). Capacity development activities for women included courses on improving managerial skills and home processing and preparation of products such as yoghurt, cheese, dried fruits and vegetables, jams, pickles, syrups and juices.

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- Agricultural Research Institute, Quetta, Pakistan
- National Agriculture Research Centre, Pakistan
- Pakistan Agricultural Research Centre
- Technology Transfer Institute, Pakistan
- Ministry of Agriculture of Baluchistan Province, Departments of Livestock, Forestry, Seed Certification, and Extension

Rescuing the Sicilo-Sarde sheep, a threatened livestock genetic resource in Tunisia

Saving and improving the Sicilo-Sarde sheep breed is helping meet the demand for milk and dairy products resulting from booming urbanization and tourism

Sicilo-Sarde ewe undergoing intra-uterine artificial insemination with frozen semen from a prime Italian Sarda ram

Overview

Native sheep and goat breeds in CWANA have significant advantages over exotic breeds. They are adapted to the harsh environments, extreme temperatures, and periods when feed is scarce. These native breeds will be invaluable in reducing risks to farmers from climate change. However, most of these breeds have not been subjected to genetic improvement and their productivity is low. In addition, they often face the effects of forces that affect genetic diversity, such as those dictated by markets.

ICARDA and Tunisian partners are key players in an innovative system that is resurrecting the native Sicilo-Sarde dairy sheep breed. The system, already being adopted by other Tunisian farmers with native sheep flocks, is proving a model for sustainable livestock development to improve the lives of rural communities.

Preserving and improving genetic integrity

The Sicilo-Sarde sheep, developed in Tunisia in the 17th century, is the only dairy sheep adapted to the dry environments of North Africa. Since 1995 this breed has undergone a population decline, from 200,000 ewes in 1995 to 25,000 ewes in the year 2000. The reduction in population numbers was also accompanied by a rapid increase in inbreeding that lowered productivity.

Enthusiastic and committed members of the Sicilo-Sarde Breed Association, formed in 2003 by a local entrepreneur, follow all possible routes to bring back the breed and realize its full potential. They actively sought information and technical help from Tunisian research organizations, involving the Agricultural University of Tunisia (INAT), the Agricultural Research Institute of Tunisia (INRAT), and ICARDA. They have also successfully lobbied for policy changes and new legislation that are benefiting sheep dairy production.

As a broker of information, ICARDA, in collaboration with INAT, INRAT and the Tunisian Livestock Development and Pasture Improvement National Program (OEP), was able to source animal genetic resources to bring the threatened Tunisian Sicilo-Sarde dairy sheep back from extinction and solve the problem of increased in-breeding. In 2005, the scientists of this research partnership arranged for 1600 Sicilo-Sarde ewes to undergo intra-uterine artificial insemination with frozen semen from prime rams of the Italian Sarda, a parental related breed. The ewes produced 409 crossbred lambs.

But, to reverse the processes affecting the integrity of this breed it is essential also to implement a long-term genetic improvement plan to produce improved breeding rams and ewes. ICARDA and its collaborators provided technical advice on setting up a breeding program for rams in 2004. In 2008, 18 farmers were using improved rams for breeding.

By 2005, the population of Sicilo-Sarde breeding ewes was 10,000. By 2008, it had reached 25,000, well on the way to the target 30,000 by 2010. Most of the males produced were used within the association and the remaining rams were sold to farmers with small flocks.

Providing farmers with skills to take advantage of booming demand

The demand for processed milk products in Tunisia has increased in recent years as a consequence of booming tourism-related activities. To take advantage of this boom in demand, the Tunisian partners have worked closely with the Sicilo-Sarde Breed Association to boost Sicilo-Sarde milk production, taking into account other production aspects as well as genetic improvement.

Researchers work with farmers on the complex inter-linked issues of sheep nutrition, reproduction, health, management, and development of marketable products. To make sure this information also gets to smaller farmers, the more prosperous members of the Association act as mentors. They also often help the

The strategy to reverse the decline of the native Sicilo-Sarde dairy sheep breed brings together key elements of an innovation system

smaller farmers with loans to improve sheep management and productivity.

As a result, per-year milk production rose to 140 kg/ewe in 2008, up from 70 kg/ewe in 2003 and on track to reach the target of 150 kg/ewe by 2010.

Diversifying and value adding

Farmers, motivated by booming demand for crop and livestock products from rapid urbanization and tourism, as in the case in North Africa, are shifting from subsistence farming to market-oriented production. But, in the Near East and North Africa only 6.3% of the total land area is arable (which is lower than in most other developing regions), and water is scarce. Shifting to higher value livestock products increases the productivity of land and water.

Processing milk into cheese converts it into a higher value product, which is more easily transported and has a longer shelf life. But, to add value to milk, farmers need to produce consistently high quality, hygienic, safe, labeled products and to market them successfully.

The entrepreneurial work of a 'champion of the community' was outstanding in this context. Leading the association of dairy sheep producers, this person managed first to promote changes in policies and negotiated with the milk processing industry an excellent price (1.55 TD/liter), well above the price for cow milk (0.55 TD/liter). The next step made by the association was to establish a milk collecting center and cheese processing units at individual farms in the region.

Bringing together key elements of the innovation system

The strategy to reverse the decline of the native Sicilo-Sarde dairy sheep breed brings together key elements of an innovation system – entrepreneurs with enthusiasm for an emerging market and a thirst for information, global and national information brokers to supply best-practice knowledge, favorable policies, support from development partners, and the willingness of all parties to work together towards a common goal.

A model for sustainable livestock development

This innovative system of participatory community-based livestock breeding gives farmers permanent access to improved breeding stock. Healthy, productive native breeds adapted to their local conditions give farmers the opportunity to take advantage of favorable policies and emerging markets to diversify and intensify their farming systems. At the same time, because native breeds are hardier than exotic breeds, farmers face fewer risks from climate change.

Tunisian farmers of the Noire de Thibar sheep breed, impressed with the success of the Sicilo-Sarde, have begun to implement the same strategy to increase meat production from their flocks. Farmers, researchers, development agencies, and policy makers too are looking at this system as a model for sustainable livestock development.

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- Tunisian Livestock Development and Pasture Improvement National Program
- Tunisian Ministry of Agriculture
- United States Department of Agriculture
- University of Natural Resources and Applied Life Sciences, Vienna, Austria

Livestock and livelihoods: dairy goats for women in Afghanistan and Pakistan

- The genetic base of village flocks is improved by bringing in improved bucks, and disease is curtailed through vaccinations
- So far 400 kids have been born to improved bucks

Overview

Women farmers have a tough life in Afghanistan and Pakistan. Years of conflict and frequent droughts have left a trail of poverty, particularly among women. Widows attempting to sustain their families by keeping goats have faced numerous problems such as death and illness in young goats and limited marketing skills and opportunities.

Since 2006, ICARDA has worked with women to rehabilitate agricultural livelihoods in marginal and post-conflict areas of Afghanistan and Pakistan. As a result, 846 women joined local women's organizations set up through the project and 400 neighboring households received spill-over benefits.

By supplementing with improved animal feeds, and vaccinating and de-worming their flocks, the women increased yields of goat milk and meat and curtailed disease. They also learnt to produce high-quality and safe dairy products for household consumption and to generate income. And, a restocking program has given Afghan women the chance to rear goats suitable for long-term gain.

Working with women

Armed conflicts in Afghanistan and Pakistan have left many women widowed: more than 1.5 million in Afghanistan alone according to some reports. These women are forced to fend for themselves and their children with few assets or economic options and very limited access to social services. Attempts by these women to rear livestock have been further hindered by increasingly severe droughts, which may be associated with global climate change.

An ICARDA project, which ran from 2006 to mid 2009, has been researching how viable goat keeping can support women affected by conflict in Afghanistan and Pakistan. With funding from the International Fund for Agricultural Development (IFAD), ICARDA aimed to improve the skills and knowledge of rural women in rearing dairy goats, processing and marketing surplus products and making the most of local resources.

Central to the project was the establishment and support of women's groups. By providing female facilitators and training women in the groups, the research team maximized the project's sphere of influence within rural communities.

Testing animal feeds

In Pakistan, women farmers tend to lack the knowledge and skills required to source good quality feed for goats. Working with women's groups in Punjab and Balochistan (300 women in total), ICARDA looked at several ways of improving this situation. One approach was to test how feeding a supplemental concentrate affected milk production and related financial benefits. Women farmers fed 68 dairy goats with 250 grams of the concentrate per head each day. The results were very positive. The supplemented goats produced 0.8 liters of milk per day, compared with 0.5 liters from other goats, and financial benefits outweighed the costs by three to one.

The ICARDA team and women farmers also investigated how feed supplements affected the fattening of male goats marketed as sacrificial animals for the Eid festival. Again, results showed a positive impact. On average, goats fed with the concentrate gained 170 grams of weight daily compared to 113 grams in unsupplemented goats. The net financial benefit per goat from this improved fattening was US$15 compared with US$7.7 using traditional feeding practices.

Another option for improving the health and productivity of goats is to use locally cultivated improved fodder, such as mulberries or maize intercropped with legumes. One example trialed was hay made from guar (*Cyamopsis tetragonoloba*). Guar, which thrives in semi-arid regions, is a leguminous plant high in protein. Hay made from the plant is therefore highly nutritious for animals such as goats, as the project participants discovered.

The team found that goats which received 2 kilograms of fresh guar hay per day produced 0.9 liters of

The female members of the associations have received… training which has been extremely valuable

milk per day, whereas goats fed in the traditional way yielded only 0.5 liters. Guar hay also greatly increased the weight gain of lactating goats: 133 grams per day compared to just 47 grams for lactating goats fed traditionally.

Restocking goat flocks

In Afghanistan, many farmers have lost livestock through the effects of war and drought. To help reestablish stock in the country, ICARDA worked with 546 women in two provinces. By setting up women's organizations, the research team established a network for restocking communal pastures with Gujri goats.

The research team chose the Gujri goat because it is a hardy breed indigenous to Afghanistan. It is resistant to diseases and can produce milk and meat under harsh conditions such as cold temperatures and high altitudes. On average, it produces 2 to 3 liters of milk per day and can give birth to one or two kids every eight months.

The team distributed 93 pregnant does and six bucks in the project area. The bucks were used for service on communal pastures, with the aim of improving the genetic base of village flocks. The pregnant does were distributed to widows or other female heads of families who didn't have assets of their own. The project was then extended to Pakistan, where the team distributed 100 does and six bucks. So far, 400 kids have been born to improved bucks in the target region in Pakistan.

In order to help farmers beyond the women's organizations, the project implemented a 'pass on the gift' policy. This is a credit-in-kind scheme, in which project participants forward a young female goat to another woman livestock farmer who does not have goats of her own. In the target region in Afghanistan, by March 2009, about 60 female kids had been passed on to second-round beneficiaries.

Controlling disease

The project also provided a vaccination and de-worming program for goats in the two Afghan provinces. Vaccination against major diseases such as enterotoxaemia increased kid survival rates and overall flock productivity by three to five times. This positive result persuaded women participating in the project that such veterinary interventions are worth the cost, especially if this is shared between households.

Developing marketing skills and strategies

In order to help women in the project areas boost their incomes, ICARDA provided training in processing and marketing. In Afghanistan, women learnt how to collect milk hygienically and to process it into yoghurt, cheese and curd. The second phase of ICARDA's work on improving the livelihoods of women in Afghanistan is starting in mid 2009, having received support from IFAD via the Livestock Department of the Ministry of Agriculture in Afghanistan. This project will equip 1000 poor women's households with successful technologies developed in the first project phase.

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Partners

Afghanistan
- Livestock Department of the Ministry of Agriculture
- SERVE - Eastern Region Community Development Project
- Dutch Committee for Afghanistan
- FAO

Pakistan
- Pakistan Agricultural Research Council (PARC) and its organizations: National Agricultural Research Centre, Animal Sciences Institute, Social Sciences Institute, Crops Sciences Institute
- Livestock Department, Government of Punjab
- Barani Livestock Production Research Institute, Barani Village Development Program
- PMAS - Arid Agriculture University, Rawalpindi
- National Rural Support Program
- Centre for Advanced Studies in Vaccinology and Biotechnology
- Arid Zone Research Centre
- Provincial organizations in Balochistan: Livestock and Dairy Development Department, Technology Transfer Institute

- Luxury Tajik mohair yarns are now on sale in the US where they fetch premium prices
- Spinners' groups can pay mohair goat keepers higher prices for good quality kid mohair now that they have access to international markets and can sell their yarn for more

Spinning a fine yarn in Tajikistan

Overview

Angora goat production and mohair marketing are vital to the livelihood of rural households in northern Tajikistan. Yet poor access to global markets and inadequate breeding and extension services are threatening the long-term viability of the sector.

Poor market access means that kid mohair is underpriced in Tajikistan, costing farmers hundreds of thousands of dollars in lost revenue. For example, in 2008 fine kid mohair sold on the Australian market for around US$30/kg. In Tajikistan, kid mohair sold for less than adult mohair – just US$4.50/kg.

An ICARDA project is helping to promote the development of the sector, increasing the incomes of small farmers and women spinners. The project focuses on helping spinners process kid mohair into luxury yarns for export, and helping farmers improve goat breeding and fiber quality standards to meet global market demand – essential activities for the sector's future survival and sustainable development in Tajikistan.

A great, but unfulfilled, livelihood opportunity

People in northern Tajikistan rely on Angora goat production and mohair marketing for their livelihoods. Mohair sales contribute about US$1.5 million to the local economy each year. Mohair provides an earning opportunity not only for small farmers, but also for rural women who spin mohair into yarn. In fact, the sales of handspun mohair yarn represent the most important source of income for rural women in the region.

Historically, Tajikistan has relied on the former Soviet Union for help with Angora goat breeding and mohair marketing, and Russia continues to be the major buyer taking over 70% of the mohair produced by adult goats. However, Russia has no processing capacity for kid mohair – used for luxury yarns and textiles – that is highly prized on the world market.

This lack of access to lucrative global markets for fine kid mohair hurts not only Angora goat farmers, but also mohair spinners. Tajik women sell coarse mohair knitting yarns to Russia for US$10/kg, while fine kid mohair yarns made in Italy, Australia and South Africa sell for as much US$580/kg in stores in the United States and Europe. However, the isolation of rural Tajik women effectively cuts them off from these markets.

In addition to limited market access, Tajik Angora goat producers lack the incentives, technologies and market information to breed for fine quality fiber.

Unlike farmers in South Africa, Australia and Argentina, who are supported by breeding and extension services and developed marketing infrastructure, Tajik producers are left without assistance in any of these areas. This is mainly due to the collapse of the state-run breeding and marketing programs that supported Angora goat production in Tajikistan during the Soviet period.

Without new programs and institutions to help them access information, know-how, new breeding technologies and markets, fiber quality and mohair prices will decline, leading to the collapse of the mohair sector. This will have dire consequences for thousands of families, whose livelihoods depend on mohair sales and processing.

Fine yarns lift women spinners' incomes to new levels

ICARDA is teaching rural women how to spin high-value, high-quality kid mohair yarns for sale in the United States. Samples are tested by American knitters, who provide direct feedback to the spinners. Spinners are also learning to use wooden spinning wheels that increase their productivity and make their work easier than it is with the traditional spindles. During this training, the project provided the spinners with fine, kid mohair for spinning, as well the spinning wheels themselves.

After two years, the women are producing beautiful yarns that can compete successfully with luxury mohair yarns sold in the United

Women are producing beautiful yarns that can compete successfully with luxury mohair yarns sold in the United States

States. They could earn US$70/kg for yarn of this quality – 7 times more than they get for coarse yarns in Russia. Assuming they buy quality kid mohair at US$10/kg, their income would be US$60/week – it takes a spinner about one week to spin one kilogram of yarn on a spindle, while performing her regular household tasks. Her productivity increases by at least 50% if she uses a spinning wheel. This means that a spinner could earn US$240–360 a month, that's 4–6 times the average per capita income.

The first Tajik yarns are now being test-marketed in the United States. In addition to spinning yarns, women are also learning to knit value-added products, such as shawls, allowing them to access the market for luxury apparel.

Fine yarns need top quality mohair

The spinners' success in producing marketable yarns depends entirely on the quality of the mohair the farmers produce. Therefore, working with farmers to improve breeding and animal maintenance is essential.

Farmers are learning how to access the information, know-how, organizations and technology they need to produce and market international-quality mohair. Angora goat breeding experts, local and international, are setting up breeding nuclei on selected farms to produce high-quality bucks. These animals will then be sold or lent to other farmers. The breeding animals are selected based on fiber characteristics such as fineness, length, volume, luster and the absence of coarse hairs (kemp).

Farmers would not invest in improving breeding and fiber quality if there was no market for fine-quality fiber. So farmers are linked up with spinners' groups who are willing to pay higher prices for quality mohair. This introduces clear monetary incentives to improve fiber quality.

In addition, as part of the technical support given, the project also collects mohair samples and analyzes them for fiber quality. A mohair evaluation system, based on international standards, is also being developed.

A bright future

The project plans to develop a cottage industry based on the production of luxury mohair yarns and knitted products for export, providing new earning opportunities for rural women, improving their families' living standards, and increasing their status within the household. At the same time the project will promote the development of institutional infrastructure that will help mohair producers to improve breeding, animal maintenance and mohair quality and to expand markets for Tajik mohair.

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Partners

- Terra Institute, University of Wisconsin, Madison, USA
- Tajik Research Institute of Livestock, Sogd Branch, Tajikistan
- Instituto Nacional de Tecnología Agropecuaria, Bariloche, Argentina
- International Fund for Agricultural Development

'Karahan-99' is one of the high-yielding wheat varieties, specifically adapted to cold areas and resistant to pests and diseases, to come out of the International Winter Wheat Improvement Project

New varieties of wheat are adopted by poorer farmers as well as the better off, bringing farmers more profits and better livelihoods

New wheat varieties boost incomes in Turkey

Overview

Turkey is a major wheat producer, harvesting 17.7 million tons, worth about US$5 billion, in 2006/7. Value-added products, such as bread and burghul, make the industry one of the major sectors of the economy.

A 2008 NARS/ICARDA study looked at the technical, economic, and social impact on farmers' livelihoods of five improved wheat varieties in five provinces of Turkey.

Most farmers grow only one or two wheat varieties. Of the five varieties, 'Pehlivan' had the third highest adoption rate of all varieties. Importantly, these varieties are being used by poor farmers as well as those who are better-off. Farmers planting the monitored varieties doubled their yields under rainfed conditions, compared with the oldest improved varieties grown in the same area; they also achieved the highest incomes. If existing government programs to increase wheat production were targeted specifically at these varieties, rural poverty reduction could be achieved faster.

Assessing adoption and impact

Researchers used descriptive analysis and econometric models to study the adoption of five new winter and spring wheat cultivars, and their impact under rainfed and irrigated conditions in different regions of Turkey. The provinces of Adana, Ankara, Diyarbakir, Erdine and Konya (together accounting for 22% of the area planted to wheat) were chosen, based on the distribution and use of the varieties included in the study.

The five varieties (called 'monitored varieties'), 'Ceyhan-99', 'Demir-2000', 'Karahan-99', 'Pehlivan', and 'Saricanak-98', had been developed jointly by Turkish research institutions, ICARDA and CIMMYT over the last 10 years under the International Winter Wheat Improvement Program (IWWIP).

The survey was carried out between January and May 2008, and 781 responses were collected from farmers by structured interview. Respondents mentioned 40 other varieties, 27 of which are grouped as 'other new' varieties and 13 as 'old-improved' varieties in this study, as well as the five monitored varieties.

Which varieties are farmers adopting?

Farmers' evaluations of new varieties are useful to breeders because they help to show whether their agronomic, quality and price performance is satisfactory from the point-of-view of the end-user. In this study, farmers preferred wheat varieties that give good yields, resist drought, fetch good prices, are well adapted to local conditions, resist frost, and produce good quality bread. They don't grow many different varieties: most grow only one (59%) or two (35%). If we rank all 45 varieties identified in this survey by adoption rate, 'Pehlivan' is third (grown by 8.2% of farmers), 'Ceyhan-99' is eighth (3.5%), 'Karahan-99' is 20th (0.9%), 'Demir-2000' is 21st (0.7%) and 'Saricanak-98' is 28th (0.5%).

Although adoption rate is an important indicator for measuring technology uptake, other indicators provide better insight into the process. In this case, both adoption degree (the area under the variety in question as a proportion of the total wheat area) and adoption intensity (adoption rate multiplied by adoption degree) follow a similar trend to adoption rate. The adoption intensity of the monitored varieties was highest at 3.8% among better-off farmers (in the highest income quartile), followed by poor farmers (lowest quartile) at 2.2%. Although the monitored varieties together have the lowest adoption degree (15.4%) of the three groups, this is not negligible given the size of the group and that fact that these varieties are still at an early stage of the adoption process.

New varieties boost farmers' yields

Overall, farmers planting the monitored varieties saw their yields double to 3.54 tons/ha under

If programs to increase wheat production were targeted specifically at these varieties, rural poverty reduction could be achieved faster

rainfed conditions, and increase by 11% in irrigated systems (4.14 tons/ha) compared to old-improved varieties. But there are regional differences. While yields under rainfed conditions in the plateau region increased by 73% (2.41 versus 1.39 tons/ha), in the lowland region the increase was only 13% (3.74 compared to 3.30 tons/ha).

Using the Cobb-Douglas production function, researchers found that adopting the monitored varieties generated a net increase of 17% in total factor productivity of wheat among producers.

This lift in productivity comes with a substantial improvement in yield stability across geographic locations. The monitored varieties had the lowest coefficients of variation among all varieties under both rainfed and irrigated conditions, indicating increased stability across years.

The monitored varieties also performed better than other varieties in terms of water productivity. They produced 0.72 kg of grain per millimeter of rainwater compared to 0.71 kg/mm for other new varieties, and 0.47 kg/mm for old-improved varieties. So the monitored varieties contribute more to risk reduction for farmers as well as better water use efficiency compared with other varieties. Since water availability is a major constraint to production in the dry areas, planting these varieties could save scarce water resources.

New varieties can bring higher profits

'Ceyhan-99', 'Pehlivan', 'Saricanak-98', and 'Karahan-99' are more profitable than all other varieties in the study, measured by gross margin per unit of land; 'Demir-2000' is the least profitable. Gross margin is higher for both the monitored varieties and the other new varieties (US$850/ha) than for the old-improved varieties (US$395/ha). In both rainfed and irrigated systems, both the monitored varieties and the other new varieties are more profitable than the old-improved varieties.

Average incomes for households using the monitored varieties are the highest: 58% higher than those using other new varieties and 87% higher than those using the old-improved varieties. The contribution of new wheat varieties to income is 54% as compared with 46% for adopters of other new varieties and 37% for non-adopters.

Impact on poverty

The monitored varieties contribute substantially to poverty reduction. Per capita income per day was estimated at US$20.6 for the whole sample; it was higher for households who adopted the monitored varieties or other new varieties. Across the provinces the highest per capita per day income was obtained in Konya (US$34), Edirne (US$26.8), and Adana (US$22.7).

Households in the lowest wealth quartile (poor farmers) increased their per capita income per day to US$14.9 by using the monitored varieties compared to those in the same wealth quartile using other new varieties (US$12.6) or old-improved varieties (US$10.6).

There is no significant difference in per capita income per day between users of the monitored varieties and other new varieties. But there is a significant difference between these groups and farmers who use the old-improved varieties.

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Partners

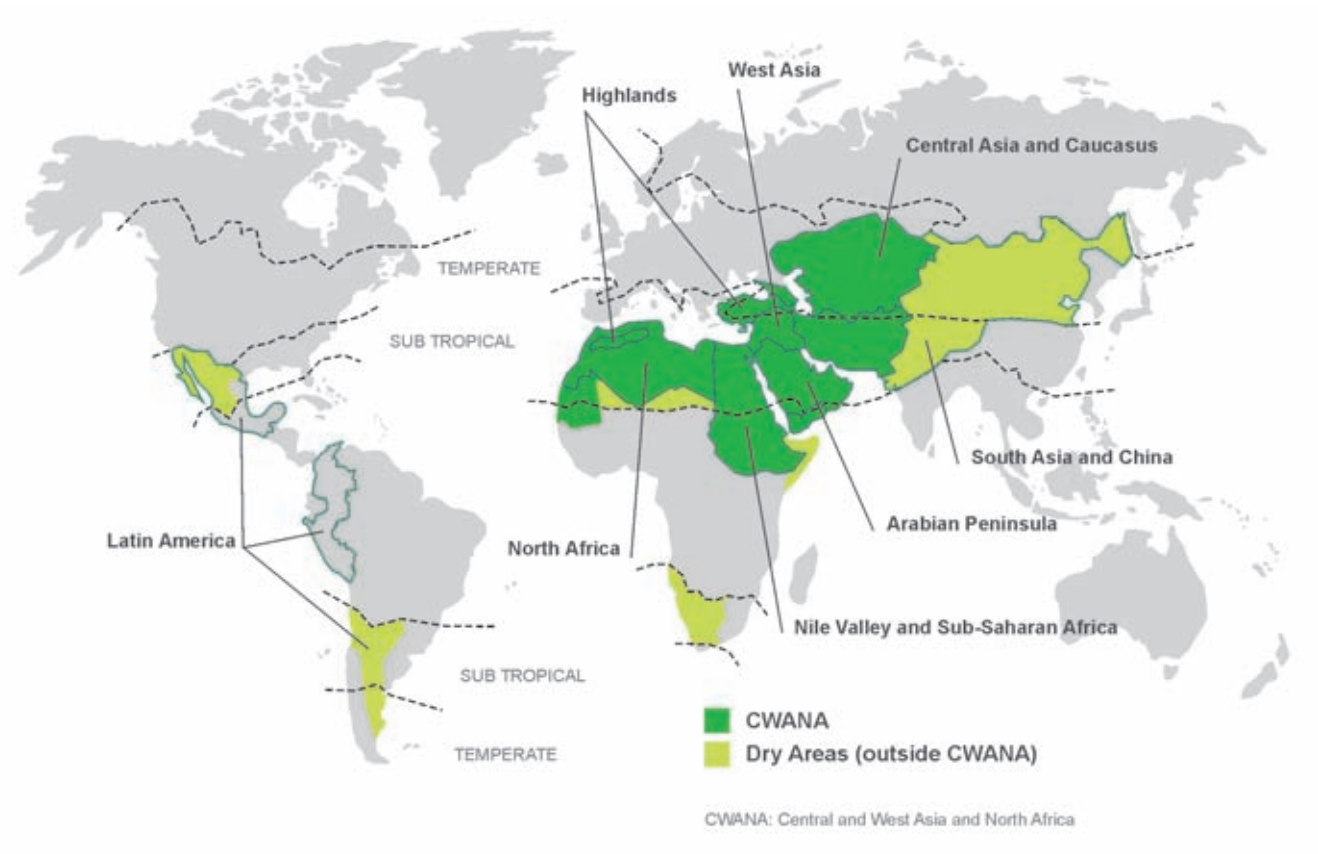
- International Maize and Wheat Improvement Center
- General Directorate of Agricultural Research, Turkey
- Selçuk University, Konya, Turkey
- European Commission

International Cooperation

Regional networks are a key ingredient in ICARDA's strategy to make sure that research really does have a strong impact on development. ICARDA's regional programs, networks and country offices vigorously promote decentralized and collaborative research partnerships, and are vibrant two-way channels for spreading successful technologies into communities and feeding back research needs to scientists. The regional programs, networks and country offices take an integrated approach to addressing the complex challenges faced in dry areas, embracing the socioeconomic and policy issues that so often block development. Not least, they offer partner NARS exceptional opportunities to strengthen their capacity.

ICARDA's global position and NARS national platforms for delivering technologies build on the strengths of each to jointly address problems of hunger and poverty. An outstanding example of the way this approach responds to global, regional, and national needs, and considers both immediate and longer term time frames, is the shuttle breeding program to develop resistance to Ug99. This virulent strain of wheat stem rust threatens to destroy the staple food crop of millions of poor in Africa and Asia. Shuttle breeding by the regional programs is fast tracking new wheat varieties resistant to Ug99.

ICARDA's Regional Programs



Nile Valley and Sub-Saharan Africa Regional Program

NVSSARP took part in a workshop on the new Middle East Water and Livelihoods Initiative in 2008

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

The Nile Valley and Sub-Saharan Africa Regional Program (NVSSARP) works in partnership with institutions in Egypt, Eritrea, Ethiopia, Sudan and Yemen.

Working with communities

In Egypt, ICARDA and national researchers began working with communities on an innovative new IFAD-funded project to analyze value chains for medicinal and aromatic plants and horticultural commodities. In Egypt, the regional program is successfully applying the village-based seed enterprise model to accelerate dissemination of improved drought-tolerant barley varieties. In Egypt and Ethiopia, a USAID-funded project is multiplying wheat seed to combat the threat of stem rust disease.

The regional water benchmark project, implemented by ICARDA with Egyptian and Sudanese scientists, is developing new technologies as well as community-led approaches to conserve and manage water. In Egypt, the new techniques reduced water and fertilizer application by 25% and 35% respectively, and increased yields by 15%.

In Ethiopia, ICARDA worked with the national research program, ILRI and BOKU (Austria) on a community-based livestock breeding system. In Eritrea, through the CGIAR Challenge Program on Water and Food, ICARDA helped develop integrated soil, water, crop and livestock packages to improve food security.

Building partnerships

In Ethiopia, ICARDA and the Ethiopian Institute of Agricultural Research have outlined plans to scale up collaboration, including opening a new ICARDA office in Addis Ababa. In Egypt, partnerships have been broadened with the Bibliotheca Alexandria and several universities.

Planning action and building capacity

In 2008, research plans were developed and new research sites identified jointly with the national programs of Egypt, Ethiopia, Sudan and Yemen, for a major international project on wheat rust Ug99. Ministers and heads of national research centers from several countries identified priority areas for collaboration; for example, plans were developed to expand wheat and faba bean research in Egypt.

NVSSARP played a key role in Arab Water Council coordination meetings to prepare position papers for the 5th World Water Forum, and to develop an action plan for the Arab Framework for dealing with climate change. A model for a regional wheat assessment mission was successfully tested in Egypt in 2008, and will be scaled out to other countries in the region.

Scientists from Egypt, Eritrea, Ethiopia and Sudan received training on topics ranging from small-scale seed enterprises and crop–livestock production to genebank management, livelihoods and poverty analysis. Several hundred staff from national research and extension programs benefited from ICARDA's capacity building programs in 2008. NVSSARP also co-organized the International Dryland Development Commission (IDDC) conference in Egypt, attended by over 450 delegates from 42 countries.

Looking ahead

ICARDA worked with NARS from Egypt, Ethiopia, Eritrea and Sudan to develop a proposal for a major regional research program on technical, institutional and policy options for improving productivity and reducing vulnerability to climate change impacts. The project will address crops and livestock, as well as land and water management.

NVSSARP and Egypt's Agricultural Research Center have developed new project proposals on water productivity, crop and livestock improvement, and agroecological zoning, which will be supported through Egypt's contribution to the CGIAR. NVSSARP is also working with Egyptian institutions to develop a regional proposal, the Middle East Water and Livelihoods Initiative.

NVSSARP, the Soil, Water and Environment Research Institute and the Desert Research Center met to review the findings of the long-term resource management trials recently completed in Egypt, and to build support for a new proposal with international funding. NVSSARP and the French research institutes CIRAD and INRA are also discussing a series of collaborative research projects on food legumes, water management and crop-livestock systems.

North Africa Regional Program

In 2008, collaboration between ICARDA and Libya's Agricultural Research Center got underway. This includes training and three 5-year research projects

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

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

Working with communities

In 2008, NARP continued its hands-on work with nine communities in six countries, as part of the Mashreq–Maghreb III Project to improve the livelihoods of agropastoralists. The Program's integrated participatory approach empowers communities to manage their resources more efficiently. Local groups participate fully in creating Community Development Plans and setting up community-based organizations. Implementing these plans makes real differences to smallholder farming, marketing, livelihoods, and rangeland management.

Communities in Tunisia now rest 20,000 ha of collective rangelands. Studies completed in 2008 showed the success of this approach in helping forage and other species recover. These collectively managed rangelands will provide long-term sustainable grazing for livestock and are a model for community management of agropastoral dry areas.

Researchers also ran the first comprehensive study of metabolic disorders in the sheep and dromedaries kept by typical livestock-keepers in southeastern Tunisia. The results will feed into work on appropriate nutrition, animal selection and disease prevention strategies adapted to the region.

Building partnerships

The Program worked with the British Society of Animal Sciences, INRA (France) and the Tunisian Ministry of Agriculture and Ministry of Environment to organize the International Conference on Livestock and Global Climate Change. This was held in Tunisia in May 2008. More than 70 papers were presented at the conference, which attracted 130 delegates from 36 countries.

In Libya, ICARDA and national institutions developed a work plan to implement the collaborative agreement signed in 2007. Team building exercises led to a shared vision, and clarified roles and responsibilities.

ICARDA signed Memorandums of Understanding with several NARS in Tunisia: the Tunisian Gene Bank, the Biotechnology Center in Borj Cedria, the Institution for Research and Higher Education in Agriculture, the Directorate of Plant Protection and the Arid Zones Institute. NARP maintained partnerships with the Morocco NARS through the Morocco Collaborative Grant Program, which funds five INRA Morocco-ICARDA projects and one technical assistant.

With the Algeria NARS, NARP continued implementing its bilateral wheat program for the fourth year. NARP also worked with institutions in the north Mediterranean Basin on EC-funded agricultural research and in organizing a course on recent trends in conservation agriculture in the region.

Planning action and building capacity

In 2008, NARP attended a number of major conferences and other regional events, and gave a keynote address at the 5th Congress of the Scientific Research Outlook in the Arab World (SRO5).

Most notably, NARP met with officials from the five countries of the region, under the leadership of the Arab Maghreb Union and with the participation of the UN Economic Commission for North Africa. At these meetings, policy makers agreed to enhance cereal production in the region by measures such as increasing the farm gate price for wheat by up to 100%. During further meetings throughout the season, farmers, decision makers, agriculturalists, development agencies, researchers and others reviewed and adjusted strategies and plans for sustainable cereal production in the region.

During 2008, NARP itself held a series of workshops, coordination meetings and training courses across North Africa. At these meetings, participants discussed topics including strategies to face the food crisis, adapting to climate change and conservation agriculture.

Looking ahead

North African national research programs are working with ICARDA to develop a concept note for a regional project on improving the productivity of cereal-based systems in Maghreb countries. Other project proposals relate to conservation agriculture (under the leadership of CIRAD, France), crop-livestock integration, communities' adaptation to climate change, and human resources development.

West Asia Regional Program

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

The West Asia Regional Program (WARP) extends across Cyprus, Iraq, Jordan, Lebanon, Palestine, Syria and the lowlands of Turkey. WARP is working with national programs to improve the livelihoods of rural communities and protect the natural resource base through research for development, human capacity building and regional collaboration. ICARDA's innovative participatory integrated watershed management approach, for example, actively involves local communities and institutions and is proving very effective in addressing the complex problems of poor production and desertification.

Working with communities

During 2008, farmers and decision makers were invited to two field days at the badia (steppe) benchmark site in Jordan, representative of the vast dry environments in West Asia. The first field day, attended by Ministry of Agriculture officials and crop and sheep farmers, demonstrated how the integrated watershed approach can produce feed for small ruminants and, at the same time, conserve soil and make efficient use of rainwater. The second field day, at Mhareb and Almajyydia, gave farmers, national agricultural staff, and decision makers an opportunity to mingle with members of the ICARDA Board of Trustees and ICARDA staff to discuss aspects of the badia project.

A Participatory Breeding Program was implemented in Jordan on barley, wheat and chickpea. Informal field days (national workshops) were held, where a group of male and female farmers visited the trials and participated in the selection of genotypes. Twenty-seven farmers selected 11 barley genotypes; 28 farmers selected 6 genotypes of wheat, and 19 farmers selected 8 chickpea genotypes. The selected lines will be evaluated next year.

Building partnerships

In 2008, ICARDA and the Lebanon National Research Institute (LARI) signed a new Memorandum of Understanding. The agreement extends ICARDA's use of the Terbol and Kaferdan Research Stations for another eight years and outlines areas of mutual interest where the two institutions will strengthen cooperation.

Following up on a Regional Forum on Promoting National Alliances Against Hunger in the Near East in 2007, ICARDA and the Jordan Alliance Against Hunger signed a Memorandum of Understanding in 2008. The partnership will contribute to reducing hunger in Jordan and achieving Millennium Development Goal 1.

Planning action and building capacity

The 14th Jordan–ICARDA Biennial Coordination Meeting, organized by the National Center for Agricultural Research and Extension, was attended by 70 representatives of Jordanian institutions and ICARDA staff. Staff from Lebanese agricultural institutions and ICARDA participated in the 10th Lebanon–ICARDA Biennial Coordination and Planning Meeting.

The ICARDA West Asia Regional Program meeting also focused on regional cooperation and discussed projects for improving food security in the region.

WARP organized a range of capacity-building events for scientists from across the region. Scientists took part in workshops and conferences, and 156 attended 19 specialized courses. Five workshops were conducted, on combating land degradation; sustainable land management in dry environments; *Brucella* diagnosis; value chain analysis; and socioeconomic/policy themes of the benchmark project. One student successfully completed a PhD on the economics of water harvesting in the badia at the University of Jordan.

Looking ahead

Two new project proposals have been developed. The first concerns integrated pest management and organic fertilizers on small farms in Iraq (to be funded by the International Fund for Agricultural Development). The other is a joint proposal with Jordan, Lebanon and Palestine, and addresses sustainable management of treated wastewater and graywater. Funding for this is being sought from the Middle East Science Foundation. Other proposals are being prepared on improving food security, addressing water scarcity, conservation agriculture, and bridging yield gaps of the major food crops.

A woman farmer explaining to the Regional Coordination Meeting her need for improved varieties

Central Asia and Caucasus Regional Program

The *Central Asia and Caucasus Regional Program* works closely with NARS on plant genetic resources, germplasm improvement, soil and water management, integrated feed and livestock production, integrated pest management, socioeconomics and policy research, and human resource development.

ICARDA's Central Asia and Caucasus Regional Program (CACRP) covers Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan in Central Asia, and Armenia, Azerbaijan and Georgia in the Caucasus. The regional office is located in Tashkent, Uzbekistan.

Working with communities

During 2008, CACRP and NARS partners organized more than 10 farmers' field days. More than 400 farmers, extension workers and researchers attended the field days and learnt about technologies developed through CACRP research. The Program provided farmers with 20 guides and brochures on new technologies for on-farm water and soil management, crop diversification and sustainable agricultural practices.

Smallholder farmers in Central Asia and the Caucasus can now access 14 new varieties of crop, officially released by ICARDA in 2008. New varieties of wheat, barley, chickpea, soybean, tomato, hot pepper and lentil are now available. This complies with ICARDA's Regional Strategy for Central Asia and the Caucasus on Plant Genetic Resources, which was finalized in 2008.

Other research in 2008 included economic assessments of improved technologies, livelihoods surveys, livestock value chain analyses, studies on integrated feed and livestock management, and sustainable land management.

Building partnerships

The Program worked very effectively with NARS during 2008, particularly through its support of the Association of Agricultural Research Institutions of Central Asia and the Caucasus. In recognition of this, the CGIAR King Baudouin 'Science Award for Outstanding Partnership' was awarded to the Program at the 2008 CGIAR Annual General Meeting.

In particular, CACRP has strengthened collaboration between ICARDA and the Georgia State Agricultural University. In September, representatives of the two organizations signed a Memorandum of Understanding outlining areas of work suitable for joint efforts.

To ensure continuity in its work, the Program is enhancing partnerships with international agencies such as the Asian Development Bank, FAO, the Global Forum on Agricultural Research, the World Bank, the International Fund for Agricultural Development, the United States Agency for International Development and the Islamic Development Bank.

Planning action and building capacity

The Program organized several regional planning and coordination meetings in 2008. More than 250 NARS partners participated in these events. And, 150 scientists, extension staff, farmers and government representatives took part in CACRP training programs. These programs covered topics including the documentation of plant genetic resources, the production and use of salt-tolerant crops, seed quality, statistical analysis, socioeconomic and policy research, and GIS.

Looking ahead

The Program has prepared proposals for new projects on conservation agriculture, crop diversification, livestock and rangeland management, mountain agriculture, enhancing the productivity of salt-prone land and water resources, and socioeconomic and policy research.

To support the Program's work in Central Asia, ICARDA and the International Food Policy Research Institute are embarking on two joint projects. One is an economic analysis of sustainable land management options in the region. Another, which will start in 2009, will look at the effects of climate change on agriculture in Central Asia and China. Both projects are funded by the Asian Development Bank.

The Program has also strengthened its staff base, with a new breeder who joined the team in September.

Researchers from the Central Asia and Caucasus region inspect this year's wheat trials

Arabian Peninsula Regional Program

The *Arabian Peninsula Regional Program* organizes and coordinates research and strengthens capacity to conserve the scarce water resources and fragile rangelands of the Arabian Peninsula.

The Arabian Peninsula Regional Program (APRP) works in seven countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates, and Yemen. In 2008, APRP launched an exciting new program to transfer winning technologies developed by previous APRP projects to smallholder farmers throughout the region. The new program shifts research from researcher-managed on-station trials to applied and adaptive research, and technology testing. Farmers themselves verify packages of improved technologies and management practices at pilot sites in each country. Other farmers and national decision-makers can see the improved systems in action at these on-farm demonstration sites, which encourages rapid adoption.

Working with communities

Smallholders' main problems are scarce and inefficient use of water, degraded rangeland, and overuse of pesticides in protected agriculture. APRP is moving forward quickly, delivering technology packages to communities that address these critical issues.

APRP, in collaboration with national programs, has introduced smallholders in the United Arab Emirates and Oman to buffel grass (*Cenchrus ciliaris*). This native of the Arabian Peninsula uses water efficiently and provides high-quality feed for animals. It can be cut 10 times a year, yielding dry matter of up to 20 tons/ha. More than 40 smallholders are growing buffel as a fodder crop. This reduces pressure on degraded rangelands and makes efficient use of scarce water.

In protected agriculture, technologies such as hydroponics make efficient use of water. But farmers need to carefully manage production and pest control to produce residue-free, high-quality fruit and vegetables, and avoid contaminating the environment.

Working with smallholder farmers in Oman, Yemen, Kuwait and the United Arab Emirates, APRP, in collaboration with national programs, introduced the integrated production and protection management (IPPM) program and soil-less production techniques. Farmers saved large amounts of water and boosted their profits through the sale of high-quality produce grown without pesticides.

Planning action and building capacity

Scientists and researchers from Bahrain, the United Arab Emirates, Kuwait, Oman, Qatar, Saudi Arabia and Yemen, and ICARDA scientists and management, developed a work plan for the new Arabian Peninsula program at the 1st Regional Technical Coordination Meeting and Regional Steering Committee Meeting.

In the United Arab Emirates, APRP and the Ministry of Environment and Water discussed objectives, expected outputs and workplans of the new research program at a two-day workshop. A similar workshop was held in Oman with more than 40 researchers, extension workers, and smallholders.

APRP organized two workshops for researchers from Bahrain, the United Arab Emirates, Oman, Qatar, and Saudi Arabia on collecting data from smallholders for socioeconomic and impact assessment of the new program, during which they tested pilot questionnaires.

Two Omani researchers received on-the-job training in the United Arab Emirates on buffel grass.

Looking ahead

ICARDA is vigorously seeking new avenues for supporting agricultural development and natural resource management in the Arabian Peninsula for this exciting new five-year program.

Researchers from Arabian Peninsula countries and ICARDA inspecting the growth of indigenous species adopted by a private farmer in the United Arab Emirates

Highland Regional Network

ICARDA's *Highland Regional Network* contributes to improving rural welfare in the harsh highlands of Afghanistan, Iran, Pakistan, and Turkey.

Poverty in the high drylands is severe, particularly in Afghanistan and Pakistan. ICARDA focuses on breeding crops that will tolerate cold, on introducing high-value crops to diversify incomes, on conserving soil and water, and on value-adding to the pastoral and crop–livestock systems that have a comparative advantage in these environments.

Afghanistan

Working with communities

In remote communities, especially in Badakhshan, potato is the second most important staple crop but harvests are poor. In 2008, ICARDA, CIP, and the Afghan National Program helped to triple the harvest, and to cut losses during storage almost entirely, by introducing high yielding potato varieties and low cost semi-underground stores. And, to ensure that good harvests continue, researchers helped farmers establish seed potato producer groups, produce disease-free seed, and improve post-harvest management and marketing.

Building partnerships

ICARDA and the Agricultural Research Institute of Afghanistan worked together to develop research projects on staple crops, livestock, and irrigation.

Planning action and building capacity

ICARDA provides crucial support to help re-establish national agricultural research in post-conflict situations. ICARDA organized 11 specialized training courses for 784 scientists and extension agents, as well as 27 field days on crop and seed production for 5249 farmers and extension staff.

Looking ahead

Wheat is the most important staple crop in Afghanistan but production is threatened by the spread of the Ug99 wheat rust eastwards from Africa and the Middle East. To avert this threat ICARDA and Afghan partners moved quickly to develop two proposals, one to produce seed of wheat resistant to Ug99 and a second to diversify wheat-based cropping systems. A third proposal addresses crop–livestock productivity and strengthening Afghan institutions. Simultaneously, the team aims to evaluate Ug99-resistant varieties and to plant trap-nurseries to monitor any possible occurrence of Ug99.

Iran

Working with communities

Participatory plant breeding of wheat and barley in communities in Kermanshah and Gamsar, launched in 2007 in collaboration with the Dryland Agricultural Research Institute and CENESTA (a national NGO), progressed well in 2008. The Provincial Agriculture Organization provided technical and financial support.

During the year, five new high-yielding and drought-tolerant varieties (of chickpea, winter bread wheat, safflower, durum wheat, and barley) resulting from the collaboration between the Dryland Agricultural Research Institute and ICARDA were released to farmers.

Building partnerships

In 2008, scientists from the Agricultural Engineering Research Institute, Soil Conservation and Watershed Management Research Center, Rural and Economic Research Center, and ICARDA successfully completed two projects in the CGIAR Challenge Program on Water and Food.

Researchers visited Tunisia and arranged for 5000 cactus pads to be shipped to Iran to extend spineless cactus cultivation for animal feed and other uses. This builds on technical backstopping by Tunisia in cactus cultivation since 2005.

Planning action and building capacity

In 2008, a virulent strain of wheat stem rust similar to Ug99 was confirmed in western Iran. ICARDA is a member of the Ministry of Jihad-e-Agriculture national committee that was immediately formed to address the threat. Iran plays a key role in monitoring the spread of Ug99 and in shuttle breeding resistant varieties.

Looking ahead

Stepping up the push to develop new wheat varieties resistant to cold and terminal drought, researchers in Iran and Turkey will start shuttle breeding winter wheat in 2009. Participatory plant breeding will be expanded to include chickpea and lentil.

The Dryland Agricultural Research Institute and ICARDA will collaborate even more closely, to develop improved winter wheat and winter barley varieties suitable for the extremely cold highlands of the CWANA region. And the Animal Science Research Institute and ICARDA will implement an IFAD-supported regional project on improving the livelihoods of rural women engaged in cashmere processing and production in eastern Iran.

Pakistan

Working with communities

ICARDA and Pakistani partners helped 22 community organizations form a watershed association to conserve water and soil, and rehabilitate degraded land over 20,000 hectares. Three communities have already built 35 water harvesting and soil conservation structures, and eight other communities have planted 1700 fruit and 2300 forage trees.

ICARDA, the Arid Zone Research Center, and the Provincial Agriculture Research and Extension Department, working with eight communities, are revitalizing wheat production in Balochistan. Farmers produced 70 tons of drought, cold and disease-resistant wheat seed, which was evaluated and certified by the federal seed certification department. Five farmers grew the new varieties on demonstration plots. Other farmers were invited to farmer days at four critical growth stages to inspect the new varieties.

ICARDA introduced communities to simple low-cost protected agriculture to diversify production, improve nutrition, generate income, and make efficient use of water and land. Communities produced 3 tons of cucumber with significantly less water and chemicals than before. Also in 2008, members of women's groups received 6 bucks and 78 does of improved breeds of goats, and 10,233 mulberry and other shrubs for feeding goats during droughts, to reduce grazing pressure on rangelands.

Building partnerships

ICARDA, the Barani Agriculture Research Institute, Arid Agriculture University, Arid Zone Research Center, and the Agricultural Research Institute worked closely on seed production, vegetable production, and tree nurseries.

The partnership between ICARDA, Vienna University and the Soil and Water Conservation Research Institute in modeling soil erosion using geographic information systems will be strengthened in 2009 when a student from Vienna University joins the program.

Planning action and building capacity

In 2008, 22 national researchers attended courses on assessing water productivity, improving water-use efficiency, and using geographic information systems.

Researchers organized demonstrations on raising vegetables, managing fruit trees, efficient irrigation, and soil conservation for 55 farmers and trained 44 people, including 20 women, to diagnose diseases, vaccinate their livestock, and to hygienically process and add value to milk products.

Looking ahead

In a very positive step towards continuing and extending long-term research on soil and water, the Soil and Water Conservation Research Institute and Center of Excellence in Water Resources Engineering have taken integrated watershed development into their mandate. The two institutions will work together to push the research on watershed development forward.

Turkey

Working with communities

A study to assess the impact of new cultivars on communities in five provinces was completed and the results analyzed. The report will be published in 2009 and launched at a conference to disseminate the findings.

In Ankara, a water harvesting system has been installed in 11 households as part of the Rooftop Water Harvesting Project and a socioeconomic study is underway.

Building partnerships

In 2008, ICARDA, 10 national agricultural research institutes, and CIMMYT forged ahead on the International Winter Wheat Improvement Program. Most work took place at the winter sites where 500 crosses were made to improve yield, and resistance to drought and diseases, especially the Ug99 wheat rust. Researchers distributed materials to 91 collaborators in 45 countries.

Planning action and building capacity

Many scientists attended international conferences, workshops, and training courses, and 34 participated in training at ICARDA HQ. Five researchers from Azerbaijan, Kazakhstan, Tajikistan, and Uzbekistan received two-month hands-on training in Turkey on winter wheat breeding.

Looking ahead

The eastward spread of the Ug99 wheat rust virus from Africa and the Middle East is a serious threat to wheat production in Turkey. Work is underway to tackle the threat before it strikes. Rust-resistant varieties have already been tested in Kenya and crosses have been made to develop new resistant germplasm. To step up the thrust, partners in Turkey and Iran will start shuttle breeding winter wheat in 2009.

Scientists from the national program, CIMMYT and ICARDA work with farmers to identify and test new wheat varieties in Afghanistan

Capacity Development

During 2008, ICARDA enhanced the capacity of 700 national researchers from 50 countries in Asia, Africa and Europe. In addition, 64 scientists from developing and developed countries were hosted by ICARDA for graduate research training (MSc and PhD). The post-graduate program was a collaboration between ICARDA and agricultural universities in developing and developed countries. The capacity building program also hosted five interns who conducted research alongside ICARDA scientists. ICARDA is keen to balance gender and hence 23% of all the ICARDA training participants in 2008 were women.

ICARDA continued its strategy to gradually decentralize its training activities by offering more training courses in the partner countries as part of its outreach programs in collaboration with national agricultural research systems (NARS) and international partners. In 2008, ICARDA offered 19 headquarters training courses (55%) and 14 in-country, sub-regional and regional courses.

In its continued efforts to respond to the evolving demands for training from NARS, ICARDA's Capacity Development Unit (CDU) facilitated and coordinated training courses covering various topics (see box). These courses were in response to needs expressed by NARS and included learning resources that covered: crop improvement, plant protection, seed technology, experimental design and data analysis, water use efficiency, gender analysis, impact assessment, application of ICT and agricultural research station management.

Selected topics covered by ICARDA training courses, 2008

Crop Improvement
- Variety evaluation, release and registration
- Cropping demonstration
- Genetic transformation and DNA markers for crop improvement
- DNA molecular marker techniques for crop improvement
- Durum end-products (Burghul, Freekeh and Pasta) processing
- Screening for drought tolerance for Eastern European countries
- Gene bank management and germplasm collection
- Crop improvement of cereals and legumes
- Training workshop on wheat breeding and biotechnology

Plant Protection
- Effective wheat rust surveillance
- Wheat rust: epidemiology, surveillance, pathotyping and screening for resistance
- Application of GPS for cereal rust monitoring in Central Asia and the Caucasus
- Diagnosis of plant viruses
- Soil-borne pathogens of wheat

Seed Science and Technology
- Training workshop on small-scale seed enterprise development
- Forage and pasture seed production

Crop and Livestock Production
- Forage and livestock production
- Integrated crop and livestock production
- Milk hygiene and milk processing
- Training workshop on enhancing livelihoods of poor livestock keepers through increasing use of fodder and forage production

Water and Land Productivity
- Water management for improved water use efficiency in the dry areas – irrigated environment
- Training workshop on participatory land and water management for livelihood resilience
- Training workshop on sustainable land management in dry environments
- Integrated land management in dry lands
- Evapo-transpiration and water productivity
- Forage evaluation for feed and soil improvement

Policy, Impact and Information
- Livelihood and poverty analysis, and adoption and impact assessment
- Agricultural information management, experimental design and data analysis
- Using modern ICT in library and informationmanagement systems
- Agricultural research station management

Study Tours
- Practical training on field crops (cereals and legumes), horticulture (vegetables and fruit trees), forages and livestock (small ruminants).

During 2008, ICARDA collaborated with many partners in capacity development. The collaboration embraced several sister regional and international agricultural research and training institutes.

Funding partners:

ACIAR
Arab Fund
ATSE Crawford Fund
DFID
GTZ
IDRC
IFAD
JICA
Kirkhouse Trust
UNDP
USAID

Education Partners:

Birmingham University (UK)
BOKU University (Austria)
Bonn University (Germany)
Columbia University (USA)
Cordoba University (Spain)
Hassan II University (Morocco)
INAT (Tunisia)
Leipzig University (Germany)
Mohammed V University (Morocco)
NARC (Libya)
Southern Cross University (Australia)
Technical University Berlin (Germany)
Tishreen and Ba'ath Universities (Syria)
Tottori University (Japan)
University of Abdelmalek Essaadi (Morocco)
Wageningen University (Netherlands)
Zurich University (Switzerland)

Research Partners:

AARI (Pakistan)
CASRII (Uzbekistan)
CIMMYT
Georgia Academy of Agricultural Science
EIAR (Ethiopia)
GRI and NAS (Azerbaijan)
INRA (Algeria)
INRA (Morocco)
INRAT (Tunisia)
IRESA (Tunisia)
Karkheh River Basin project (Iran)
NARC (Libya)

Development Partners:

FAO
UNIDO
UNU

Iraqi agricultural scientists learn integrated pest management techniques on an ICARDA training course.

Appendix 1: Journal Articles

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Appendix 2: ICARDA's Donors and Investors in 2008

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

Unrestricted Funding

Australia
Belgium
British Society of Animal Science (BSAS)
Canada
China
France
Germany
India
Iran
Italy
Japan
Norway
South Africa
Sweden
Switzerland
Syria
United Kingdom
United States of America
World Bank (IBRD)

Restricted Funding/Grants

Alberta Agricultural and Rural Development – Canada (AARD)
Arab Fund for Economic and Social Development (AFESD)
Arab Science and Technology Foundation (ASTF)
Asian Development Bank (ADB)
Australia
Austria
Authority of Merowi Dam Area for Agricultural Development (AMDAAD)
BASF, Germany
British Society of Animal Science
Canada
Center for Development Research (ZEF), University of Bonn
CGIAR
CGIAR Challenge Programs
Cornell University
Denmark
Development Alternatives, Inc./USAID
Egypt
El Fondo Regional Tecnologia Agropecuaria (FONTAGRO)
Ethiopia
European Commission
Food and Agriculture Organization of the United Nations (FAO)
FAO/UNEP
General Commission for Scientific Agricultural Research, Syria
Germany
Global Crop Diversity Trust
GM-UNCCD
Government of Portugal
Gulf Cooperation Council
India
INRA-INRAT
International Atomic Energy Agency (IAEA)
International Development Research Centre (IDRC)
International Fund for Agricultural Development (IFAD)
Iran
Iraq – Kurdistan Regional Government
Italy
Japan
Japan International Research Center for Agricultural Sciences (JIRCAS)
Korea
Libya
L' Institution de la Recherche et de l'Enseignement Superieur Agricoles (IRESA)
Morocco
OPEC Fund for International Development (OFID)
PADCO/USAID
Pakistan
Switzerland
Syria
Texas AgriLife Extension and Services
Tottori University, Japan
Turkey
UK Department for International Development (DFID)
UNDP
University of Illinois
University of Saskatchewan
University of Wisconsin
USAID
USDA
World Bank (IBRD)
World Food Programme

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

CGIAR Centers and Regional/International Organizations

- Arab Authority for Agricultural Investment and Development
- Arab Center for Studies of Arid Zones and Dry Lands
- Arab Organization for Agricultural Development
- Asia Pacific Association of Agricultural Research Institutes
- Association of Agricultural Research Institutes in the Near East and North Africa
- Bioversity International
- Borlaug Global Rust Initiative
- Central Asia and the Caucasus Association of Agricultural Research Institutes
- CGIAR Challenge Program on Water and Food
- CGIAR Knowledge Sharing Project
- CGIAR System-wide Livestock Program
- Economic Cooperation Organization
- European Cooperation in the field of Scientific and Technical Research (COST)
- Food and Agriculture Organization of the United Nations (FAO)
- Global Forum on Agricultural Research
- International Atomic Energy Agency
- International Center for Biosaline Agriculture (ICBA)
- International Center for Tropical Agriculture (CIAT)
- International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM)
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
- International Development Research Center, Canada
- International Food Policy Research Institute (IFPRI)

- International Livestock Research Institute (ILRI)
- International Maize and Wheat Improvement Center (CIMMYT)
- International Potato Center (CIP)
- International Rice Research Institute (IRRI)
- International Seed Testing Association
- International Water Management Institute (IWMI)
- Man and the Biosphere Programme, UNESCO
- Observatoire du Sahara et du Sahel and Oasis
- TerrAfrica partnership
- United Nations University
- World Vegetable Center (AVRDC)

Argentina
- Instituto Nacional de Tecnología Agropecuaria

Australia
- Australian Winter Cereals Collection
- Centre for Legumes in Mediterranean Agriculture (CLIMA)
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Cooperative Research Centre for Molecular Plant Breeding
- Department of Agriculture and Food, Western Australia
- Department of Primary Industries, Victoria
- Grain Foods Cooperative Research Centre
- Grains Research and Development Corporation
- Murdoch University
- New South Wales Department of Primary Industry
- Pulse Breeding - Australia
- Queensland Department of Primary Industries and Fisheries
- South Australia Department of Agriculture
- South Australian Research and Development Institute
- Southern Cross University
- University of Adelaide, Waite Institute
- University of Queensland
- University of South Australia
- University of Sydney, Plant Breeding Institute
- University of Western Australia

Austria
- University of Zurich
- Landwirtschaftlich-chemische Bundesversuchsanstalt
- University of Natural Resources and Applied Life Sciences

Belgium
- University of Ghent
- University of Leuven

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

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

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

Germany
- BASF Corporation
- Biologische Bundesanstalt für Land- und Forstwirtschaft
- Bundesministerium für Wirtschaftliche Zusamennarbeit und Entwicklung (BMZ)
- Deutsche Gesellschaft fur Technische Zusamennarbeit (GTZ)
- Deutsche Sammlung von Mikroorganismen und Zellkulturen
- Humboldt University of Berlin
- IPK-Gatersleben
- Leibniz Institute of Plant Genetics and Crop Plant Research
- University of Aachen
- University of Bonn
- University of Frankfurt am Main
- University of Giessen
- University of Goettingen
- University of Hannover
- University of Hohenheim
- University of Kiel

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

Japan
- Japan International Research Center for Agricultural Sciences (JIRCAS)
- Research Institute for Humanity and Nature
- Tottori University
- Yokohama City University

Netherlands
- Alterra
- Vrije Universiteit, Amsterdam
- Wageningen University and Research Centre

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

Spain
- Consejo Superior de Investigaciones Científicas
- Instituto de Agricultura Sostenible (IAS-CSIC)
- Instituto de Investigación y Formación Agraria y Pesquera
- Spanish National Research Council (CSIC)
- University of Barcelona
- University of Córdoba
- University of Lleida and Institut de Recerca i Tecnologia Agroalimentàries (UdL-IRTA)
- University of the Basque Country

Sweden
- Nordic Genetic Resource Center
- Swedish University of Agricultural Sciences

Switzerland
- North-South Forum (formerly Swiss Centre for International Agriculture)
- Station Fédérale de Recherches Agronomiques de Changins (RAC)
- Swiss Federal Institute of Technology (ETH)
- University of Bern

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

United States of America
- Borlaug Institute, Texas A&M University
- Brigham Young University, Utah
- Busch Agricultural Resources Inc.
- Cornell University
- Kansas State University
- Michigan State University
- New Mexico State University
- North Dakota State University
- Oregon State University
- Purdue University
- Stephen Austin State University
- University of Arizona
- University of California, Davis
- University of California, Riverside
- University of Delaware
- University of Florida, Gainesville
- University of Hawaii
- University of Illinois at Urbana-Champaign
- University of St. Paul, Minnesota
- University of Vermont
- University of Wisconsin
- Utah State University
- Virginia Polytechnic Institute and State University
- Washington State University
- Yale University

Appendix 4: Financial Summary

Statement of Activity (US$x000)

	2008	2007
REVENUES		
Grants (core and restricted)	30,243	27,557
Other revenues and gains	1,828	1,062
Total revenues and gains	**32,071**	**28,619**
EXPENSES AND LOSSES		
Program-related expenses	27,749	23,171
Management and general expenses	5,335	4,825
Other losses and expenses	499	48
Total expenses and losses	33,583	28,044
Indirect cost recovery	(1,416)	(1,113)
Net expenses and losses	**32,167**	**26,931**
SURPLUS (DEFICIT)	**(96)**	**1,688**

Statement of Financial Position (US$x000)

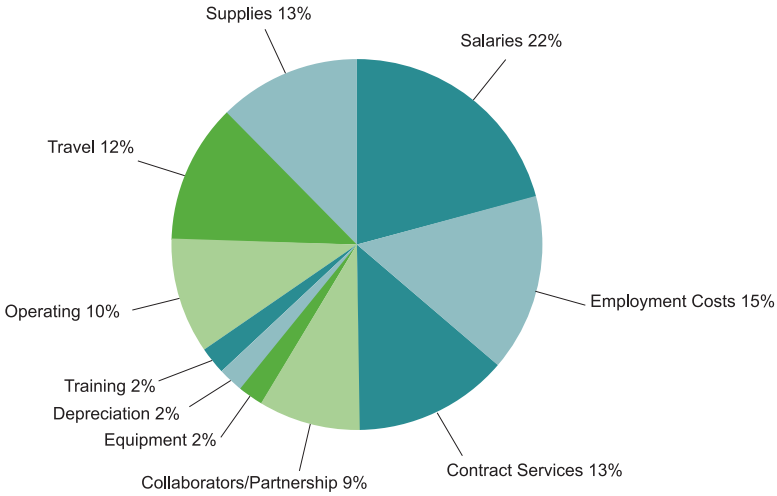
	2008	2007
ASSETS		
Current assets	37,451	29,904
Property and equipment	3,091	3,150
Other assets	-	5,223
Total assets	**40,542**	**38,277**
LIABILITIES AND ASSETS		
Current liabilities	20,170	15,931
Long-term liabilities	6,879	8,757
Total liabilties	27,049	24,688
Net assets = reserves	13,493	13,589
Total liabilities and net assets	**40,542**	**38,277**

Statement of Grant Revenues, 2008 (US$x000)

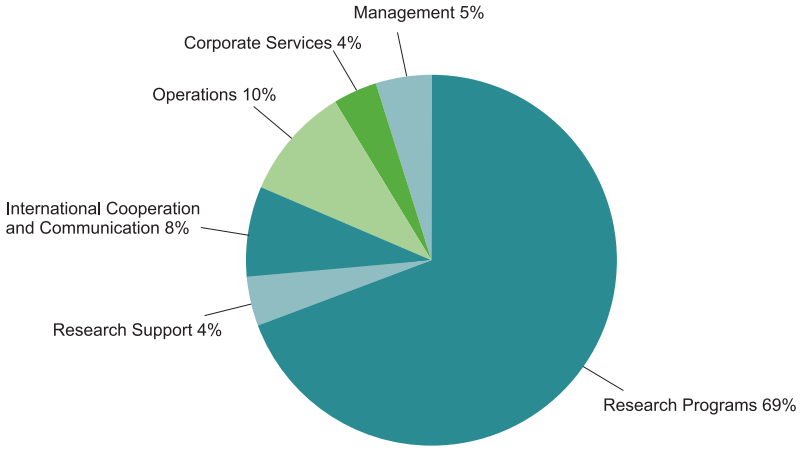
Donors	Amount
Arab Fund	968
Asian Development Bank	463
Australia*	1,545
Austria	475
Belgium*	509
Canada*	1,105
CGIAR	1,151
Challenge Programs	1,333
Cornell University, USA	496
DAI/USAID	1,092
Egypt	201
European Commission	1,133
FAO	592
France*	214
Germany*	813
Global Crop Diversity Trust	192
Gulf Cooperation Council	564
IDRC, Canada	418
IFAD	2,097
India*	334
Iran*	209
IRESA, Tunisia	162
Italy*	877
Japan*	261
Libya	235
Morocco	177
Norway*	1,233
OFID	308
PADCO/USAID	291
Pakistan	661
Sweden*	598
Switzerland*	467
Syria*	520
Tottori University, Japan	212
Turkey	242
UNDP	199
United Kingdom*	2,283
United States of America*	2,570
World Bank*	1,810
Miscellaneous	1,233
TOTAL	**30,243**

* Donors that provided core funds

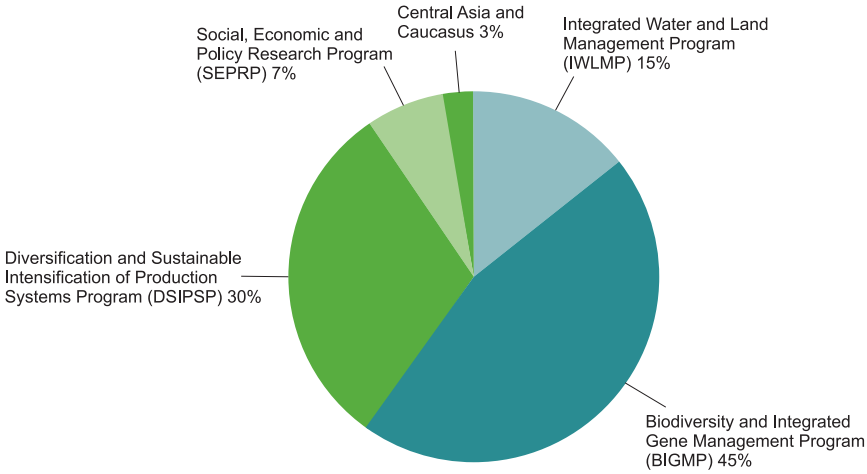
Expenditures by Category



Expenditures By Program and Activities



Expenditures by Research Program



Appendix 5: Board of Trustees

Dr Guido Gryseels (Belgium)
Board Chair
Director, Royal Museum for Central Africa, Belgium
Expertise: agricultural science

Dr Mohamed S. Zehni (Libya)
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Expertise: plant physiology

Dr Aigul Abugalieva (Kazakhstan)
Head, Grain Biochemistry & Quality Laboratory, Center for Crop Science & Farming, Kazakhstan
Expertise: biotechnology

Dr Michel A. Afram (Lebanon)
President & Director General, Lebanese Agricultural Research Institute, Lebanon
Expertise: agricultural education and policy

Dr Talal Bakfalouni (Syria)
Deputy Head, State Planning Commission, Syria
Expertise: medicine

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Olympus Management, LLC, Washington, D.C., USA
Expertise: management and administration

Dr Camilla Toulmin (United Kingdom)
Director, International Institute for Environment & Development, United Kingdom
Expertise: development economics and climate change

Dr Mahmoud Solh (Lebanon) *ex officio*
Director General, ICARDA, Syria
Expertise: genetics

Appendix 6: Senior Staff (as of 31 December 2008)

Headquarters – Aleppo, Syria

Director General's Office
Dr Mahmoud Solh, Director General
Dr Ahmed El-Ahmed, Assistant Director General – Government Liaison
Dr Scott Christiansen, Executive Assistant to the Director General
Mr Koen Geerts, Assistant Director General – Corporate Services
Mr Michael Mgonja, Internal Auditor*
Ms Houda Nourallah, Administrative Officer – DG/BOT
Dr Rajendra Singh Paroda, Assistant Director General - International Cooperation**
Dr John Ryan, Consultant
Dr Maarten van Ginkel, Deputy Director General – Research

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

Corporate Services
Mr Koen Geerts, Assistant Director General

Physical Plant Unit
Mr Waheed S. Quader, Head*

Purchasing and Supplies – PSD
Mr Frisco Guce, PSD Manager

Personnel Services
Ms Lina Yazbek, Coordinator

Visitors Services
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Appendix 7: Acronyms

AARI	Ayub Agricultural Research Institute, Pakistan
ACIAR	Australian Centre for International Agricultural Research
ADP-E	Alternative Development Program/East, USAID
ANAS	Azerbaijan National Academy of Sciences
APRP	Arabian Peninsula Regional Program, ICARDA
ARI	Agricultural Research Institute, Pakistan
ATSE	Australian Academy of Technological Sciences and Engineering
AZRC	Arid Zone Research Centre, Pakistan
BGRI	Borlaug Global Rust Initiative
BOKU	University of Natural Resources and Applied Sciences Vienna, Austria
CAC	Central Asia and Caucasus
CACRP	Central Asia and Caucasus Regional Program, ICARDA
CASRII	Central Asian Scientific Research Institute of Irrigation, Uzbekistan
CDU	Capacity Development Unit, ICARDA
CENESTA	Centre for Sustainable Development and Environment, Iran
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
CWANA	Central and West Asia and North Africa
DANIDA	Danish International Development Agency
DFID	Department for International Development
DNA	Deoxyribonucleic acid
ECO	Economic Cooperation Organization
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization of the United Nations
FIGS	Focused Identification of Germplasm Strategy, ICARDA
GDP	Gross domestic product
GRI	Genetics Resources Institute, Azerbaijan
GTZ	German Technical Cooperation Agency
GUS	Beta -glucuronidase
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICT	Information and communications technology
ICT-KM	Information, Communication Technology and Knowledge Management Program, CGIAR
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
INAT	Institut National Agronomique de Tunisie, Tunisia
INRA	Institut National de la Recherche Agronomique, Algeria
INRA	Institut National de la Recherche Agronomique, France
INRA	Institut National de la Recherche Agronomique, Morocco
INRAT	Institut National de la Recherche Agronomique de Tunisie, Tunisia
IPG	International public good
IRESA	Institution de Recherche et d'Enseignement Supérieur Agricole, Tunisia
IWMI	International Water Management Institute
IWWIP	International Winter Wheat Improvement Program
JICA	Japan International Cooperation Agency
LARI	Lebanon Agricultural Research Institute
NARC	National agricultural research center
NARI	National agricultural research institute
NARS	National agricultural research systems
NCARE	National Center for Agricultural Research and Extension, Jordan
NGO	Non-governmental organization
NVSSARP	Nile Valley and Sub-Saharan Africa Regional Program, ICARDA
OEP	Office de l'Elevage et des Pâturages, Tunisia
PA	Protected agriculture
PARC	Pakistan Agricultural Research Center
PCR	Polymerase chain reaction
PEG	Polyethylene glycol
PRODESUD	Agro-pastoral Development and Local Initiatives Promotion Program in the South-East, Tunisia
QTL	Quantitative trait locus
R4D	Research for Development, DFID
RIL	Recombinant inbred lines
SLM	Sustainable land management
SSR	Simple sequence repeat
SWAT	Soil and Water Assessment Tool
TAGEM	General Directorate of Agricultural Research, Turkey
TTI	Technology Transfer Institute, Pakistan
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
UNU	United Nations University
USAID	United States Agency for International Development
VBSE	Village-Based Seed Enterprise
WARP	West Asia Regional Program, ICARDA

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