

International Center for Agricultural Research in the Dry Areas



ICARDA

ANNUAL REPORT 2009



www.icarda.org

SYRIA - Aleppo (Headquarters)

P.O. Box 5466, Aleppo
Physical address: Tel Hadya, Aleppo-Damascus Highway
Tel: +963-21-2213433
Fax: +963-21-2213490
E-mail: ICARDA@cgjar.org

SYRIA - Damascus

P.O. Box 5908, Damascus
Tel: +963-11-3331455
Fax: +963-11-3320483
E-mail: ICARDA-damascus@cgjar.org

AFGHANISTAN

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

EGYPT

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

GEORGIA

c/o Georgia State Agricultural University
13 km, Davit Agmashenebis Kheivani
Tbilisi 0131
Tel/Fax: +99532 594290
E-mail: d.bedoshvili@cgjar.org

INDIA

NASC Complex, CGIAR Block, DPS Marg, New Delhi
110012
Tel: +91-11-25847500/25847502
Fax: +91-11-25847503
E-mail: ICARDA-SARP@cgjar.org

IRAN

P.O. Box 19395, Tehran 111
Tel: +98-21-22400094
Fax: +98-21-22401855
E-mail: ICARDA-Iran@cgjar.org

JORDAN

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

LEBANON - Beirut

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

LEBANON - Terbol Research Station

Beka'a Valley, Terbol
Tel: +961-8-955127
Fax: +961-8-955128
E-mail: ICARDA-Terbol@cgjar.org

MOROCCO

B.P. 6299, Rabat - Instituts, Rabat
Tel: +212-537-682909
Fax: +212-537-675496
E-mail: icardarabat@yahoo.fr

OMAN

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

PAKISTAN

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

SUDAN

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

TUNISIA

B.P. 435, Menzeh I - 1004, Tunis
Tel: +216-71-752099
Fax: +216-71-753170
E-mail: a.radhia@cgjar.org

TURKEY

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

UNITED ARAB EMIRATES

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

UZBEKISTAN

P.O. Box 4564, Tashkent 100 000
Tel: +998-71-2372169
Fax: +998-71-1207125
E-mail: ICARDA-Tashkent@cgjar.org

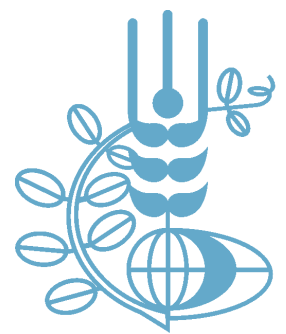
YEMEN

P.O. Box 87148, Dhamar
Tel & Fax: +967-6-423951
E-mail: icarda@yemen.net.ye

Cover photo: Lentil production in Ethiopia has tripled in the past 10 years, thanks to Ethiopia-ICARDA research partnerships. This has not only improved food security, nutrition and farmers' incomes, but also created new employment opportunities. For example, a thriving small-scale processing industry has developed, supplying decorticated (split) lentil to Addis Ababa and other markets.

Annual Report

2009



ICARDA

International Center for
Agricultural Research
in the Dry Areas

Copyright © 2010 ICARDA (International Center for Agricultural Research in the Dry Areas)

All rights reserved. ICARDA encourages fair use of this material for non-commercial purposes with proper citation.

Citation:

ICARDA. 2010. ICARDA Annual Report 2009. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria. iv + 68 pp.

ISSN: 0254-8313

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; land degradation; rangeland degradation; drought; heat; conservation agriculture; Middle East; North Africa; West Asia; Central Asia and the Caucasus.

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

All responsibility for the information in this publication remains with ICARDA. The use of trade names does not imply endorsement of, or discrimination against, any product by the Center. Maps have been used to support research data, and are not intended to show political boundaries.

Contents

Foreword	iv
Highlights of the Year	1
ICARDA's Research Portfolio	13
Biodiversity and Integrated Gene Management	14
Integrated Water and Land Management	26
Diversification and Sustainable Intensification of Production Systems	32
Social, Economic and Policy Research	40
Research Support	43
Geographic Information Systems	43
Station Operations	44
Capacity Development	45
International Cooperation	46
Nile Valley and Sub-Saharan Africa Regional Program	47
North Africa Regional Program	48
West Asia Regional Program	49
Central Asia and Caucasus Regional Program	50
Arabian Peninsula Regional Program	51
Highland Regional Network	52
South Asia and China Regional Program	55
Appendices	56
1. Journal Articles	56
2. ICARDA's Donors and Investors in 2009	60
3. Collaboration with Advanced Research Institutes and Regional and International Organizations	61
4. Financial Summary	63
5. Board of Trustees	65
6. Senior Staff	66
7. Abbreviations	68

Foreword

The dry areas face severe challenges to sustainable development. The biggest challenges – food insecurity, water scarcity, land degradation, and climate change – are closely inter-related. The effects of climate change will be felt globally, but the dry areas will be particularly hard hit. Climate change will exacerbate water scarcity, rainfall variability, and the decline in the natural resource base, and thus could have a profound impact on food security.

Food security and climate change have become priority issues for decision makers. The scientific community must play a leading role in finding solutions – providing farmers with new technologies, and policy makers with better information. ICARDA has a clear focus and, over the last three decades, has conducted successful research in dry areas, developing technologies to improve food security despite water scarcity and climate variability and change.

This report highlights some of the successes achieved by the Center and its partners in addressing these issues. Effective partnerships with national research programs, and generous support from donors, has helped the Center reach farmers, policy makers and other stakeholders, and contribute to poverty reduction and improvements in food and nutritional security.

The year 2009 saw a major expansion of ICARDA's work in both Africa and Asia. A new office was opened in Ethiopia in October. Building on ICARDA's long-standing partnership with the Ethiopian Institute of Agricultural Research, the office will provide support for collaborative activities in Ethiopia and other countries in sub-Saharan Africa. In China, a new Center of Excellence for Dryland Agriculture was established jointly by the Chinese Academy of Agricultural Sciences, ICARDA and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The first coordination meeting of ICARDA's Regional Program for South Asia and China, held in December, highlighted the strong national support from every partner country – Bangladesh, Bhutan, China, India, Nepal and Pakistan – and the need to further expand collaborative research.

Partners from 35 countries attended ICARDA's biennial Presentation Day in May 2009. The program

included presentations by guest speakers, who discussed potential responses to the multiple crises (food-related, environmental, financial and others) faced by developing countries, and the implications of climate change for agriculture in the dry areas.

Dr Guido Gryseels, Chair of ICARDA's Board of Trustees since 2006, completed his term as a member of the Board. In a farewell letter to Board colleagues, Dr Gryseels said: *"Of all the things I have done in my life, few have been so challenging, so interesting, and so rewarding as to serve on ICARDA's Board of Trustees"*. Mr Henri Carsalade will succeed him as Chair on 1 January 2010.

And, finally, ICARDA joins many others in paying tribute to Nobel Peace Prize Laureate, Dr Norman Borlaug, who passed away in 2009. Dr Borlaug was one of ICARDA's founding fathers: in 1975 he led the team of experts that selected Tel Hadya as the site for the new Center's headquarters. In his honor, ICARDA has established a Borlaug Young Scientist Award in wheat improvement research.



Mahmoud Solh
Director General

Guido Gryseels
Chair, Board of Trustees

Highlights of the Year

With food security and climate change becoming critical issues for sustainable development, ICARDA's experience in dry-area agriculture has come to the fore. For more than three decades, ICARDA and its partners have developed a range of improved technologies suited to small-scale farmers in environments with scarce water and highly variable climate. This report describes how these technologies are helping to improve food security and livelihoods, and strengthen climate change mitigation and adaptation, in some of the world's poorest regions.

Crops for a changing climate

New crop varieties developed by ICARDA and its partners are helping small-scale farmers to cope with climate change. In the 2009 season, Yundamai-2, a barley



New legume varieties are helping to reduce farmers' vulnerability to the impacts of climate change



A new lentil variety called Moitree, meaning friendship, gives yields 50% higher than varieties currently available

variety developed from ICARDA germplasm, produced the highest yield of the crop ever recorded in China: 10.8 metric tons per hectare (t/ha). In Ethiopia, 35,000 farmers planted MisCal21, a high-yielding barley variety developed jointly with the Ethiopian Institute of Agricultural Research. India released Moitree (Friendship), a new disease-resistant, early-maturing lentil. In Afghanistan, two new mung bean varieties developed by the Afghan Ministry of Agriculture, the World Vegetable Center, and ICARDA were released that produce 50-60% more than traditional varieties.

These new varieties yield more and are more adaptable to variable weather. For example, new wheat varieties developed jointly with Turkey's national research program give stable yields in dryland environments with erratic rainfall: their coefficient of variation is 28%, compared with 61% in older varieties.

The Center's participatory plant breeding program – scientists and farmers working together to test

and select varieties for specific environments – continues to be highly successful. In 2009, new varieties selected in this way for very dry areas in Syria yielded 25-30% more than the most popular landrace and 19-25% more than improved varieties. Yields of new varieties selected for wetter areas exceeded those of the most popular landrace by up to 80% and those of improved varieties by up to 26%. In Hama province, where barley accounts for a third of the cropped area, a survey conducted jointly by ICARDA and the General Commission for Scientific Agricultural Research showed that 90% of the barley varieties grown had been developed through participatory methods.

In Iran, the Center's chickpea breeders and national research centers identified three chickpea genotypes that are extremely hardy, surviving at temperatures as low as -17°C . Using these genotypes, researchers are now developing cold-tolerant varieties for highland areas.

Varieties released in 2009, developed from ICARDA germplasm

Crop	Country	Name	Characteristics
Barley	China	Yunging-1	High yield, hull-less variety, resistant to major diseases
Barley	India	PL 807	Feed barley variety, highly resistant to lodging, multiple disease resistance, suitable for favorable environments
Barley	India	BHS 380	Dual purpose variety with high forage and grain yields, resistant to rust diseases and spot blotch
Chickpea	Tajikistan	Hisor-32	High yield, resistant to fungal diseases, suitable for mechanized harvesting
Chickpea	Turkey	Aksu	Cold-tolerant, resistant to <i>Ascochyta</i> blight
Faba bean	Tunisia	Najah	High yield, resistant to <i>Orobanche</i>
Lentil	Nepal	Sagun	High yield, moderate resistance to rust, wilt and <i>Stemphylium</i> blight
Lentil	Nepal	Maheshwar Bharathi	High yield, moderate resistance to rust, wilt and <i>Stemphylium</i> blight
Lentil	Pakistan	Punjab Masoor 2009	High yield, red seeds, adapted to warm areas
Lentil	Pakistan	Markaz 2009	High yield, drought-tolerant, resistant to lodging, <i>Ascochyta</i> blight, rust and wilt
Lentil	Iran	Kimiya	Widely adapted, early-maturing, tolerant to <i>Ascochyta</i> blight, wilt and moderate cold
Lentil	Morocco	Chakkouf	Large seeds, drought-tolerant, resistant to rust and <i>Ascochyta</i> blight
Durum wheat	Morocco	Faraj	Resistant/tolerant to several pests and diseases: Hessian fly, stripe, leaf and stem rusts and <i>Septoria</i>
Durum wheat	Tunisia	Selim	High yield, tolerant to <i>Septoria</i>
Durum wheat	Ethiopia	Maamouri-3	High and stable yield, resistant to stripe, leaf and stem rusts
Durum wheat	Iran	Saj-1	High yield, drought-tolerant, good quality grain
Durum wheat	Syria	Cham-9	High yield, drought-tolerant, resistant to stripe, leaf and stem rusts
Spring bread wheat	Egypt	Sids-2	High yield, suited to irrigated environments
Spring bread wheat	Egypt	Almaz-6	High yield, suited to irrigated environments
Spring bread wheat	Iran	Bahar	High yield, suited to irrigated non-coastal environments
Winter/facultative wheat	Spain	05THES506	High yield, good bread-making quality

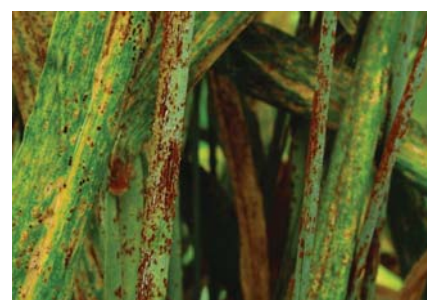
Combating the global threat of wheat stem rust

A virulent new race of stem rust disease, Ug99, threatens global production of wheat – the staple food of more than two billion people. Over 80% of the world's cultivated wheat varieties are highly susceptible to the new race, which has spread from East Africa, across the Red Sea to the Arabian Peninsula and West Asia, and now threatens vast wheat production areas in Asia.

ICARDA, together with the International Maize and Wheat

Improvement Center (CIMMYT), FAO, Cornell University and national partners, co-founded the Borlaug Global Rust Initiative in 2005 to fight rust diseases and particularly to tackle Ug99. In a significant step forward in 2009, scientists found that many of ICARDA's elite bread wheat lines were resistant to the new race. Through DNA analysis, researchers also unraveled the genetics of stripe rust. These findings will help fight the spread of wheat rusts.

ICARDA and its partners have continued to evaluate varieties for



ICARDA and its partners are working together to halt the spread of wheat rust diseases

Ug99 resistance, speeded up seed multiplication of resistant varieties, and trained national researchers to detect and manage the disease. Nine countries –

Highlights of the Year

Afghanistan, Eritrea, Libya, Mauritania, Rwanda, Sudan, Tanzania, Tunisia, and Uganda – received seed of two new Ug99-resistant wheat varieties developed and multiplied in Egypt by the Agricultural Research Center (ARC) and ICARDA.

In September 2009, ICARDA hosted a major international conference on halting the spread of Ug99 and forestalling the emergence of new races. Representatives of national research systems in 32 countries, ICARDA, CIMMYT, the United Nations Food and Agriculture Organization (FAO), American universities, and many others, signed the Aleppo Declaration agreeing on measures to combat the disease.

Advances in seed systems

Shortage of seed often hampers the spread of new varieties. ICARDA and its partners work to strengthen seed delivery systems at all levels, from village seed production enterprises to regional seed markets. ICARDA played a key role in an Economic Cooperation Organization (ECO) and FAO project to strengthen the seed sector in ECO countries. In 2009, Ministers of Agriculture in Afghanistan, Azerbaijan, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkey, Turkmenistan, and Uzbekistan endorsed a regional seed regulatory framework. The framework simplifies movement of seed and germplasm across the region.

Sharing and conserving genetic resources

In 2009, ICARDA shipped over 13,000 accessions of traditional landraces, wild crop relatives, improved populations, and breeding lines to national research

programs worldwide for use in developing new varieties. The Center, a partner in the Svalbard global initiative to conserve plant diversity, also sent nearly 64,000 accessions to the Svalbard vault in Norway. The vault now houses over 94,000 accessions from ICARDA – more than any other research center.



Seeds from ICARDA's genebank being prepared for shipment to the Svalbard vault in the Arctic Circle

Biotechnology for food security

Biotechnology will play a vital role in ensuring food security in the future, but transgenic plants must be developed and tested in complete safety. ICARDA leads biotechnology research in the Central and West Asia and North



A new state-of-the-art biosafety facility was installed at ICARDA's headquarters in 2009

Africa (CWANA) region and, in 2009, set up a new biosafety facility at its headquarters in Syria. The facility strengthens ICARDA's role not only in biotechnology research, but also as a training center.

Conserving water

Sustainable management of water resources is critical to food security in dry areas. ICARDA is applying participatory approaches at benchmark sites in 10 countries to help communities manage water more productively and efficiently.

In 2009, following successful pilot projects, ICARDA, supported by the Arab Fund for Economic and Social Development (AFESD), began scaling out technologies more widely. In Iran, the results of projects on watershed management and agricultural water productivity in the Karkheh river basin are now being used by scientists and policy makers to improve water productivity and the resilience of ecosystems in dry areas.

Work at the benchmark sites combined two key elements of water management – rainwater



Rainwater harvesting is helping to rehabilitate dry rangeland areas in Jordan, one of the world's most water-scarce countries

harvesting and supplemental irrigation – with other ways of conserving water, such as planting regimes and irrigation scheduling. Farmers using these combinations ('packages') have achieved impressive results. In Morocco, wheat yields increased from 4.6 t/ha to 5.8 t/ha, and water productivity (the amount of seed produced from a cubic meter of water) increased by 50%. In Iran, wheat yields increased from 2.4 t/ha to 3.8 t/ha, barley yields from 2.2 t/ha to 3.4 t/ha, and water productivity nearly doubled. In Turkey, wheat yields increased from 3.4 t/ha to 5.3 t/ha, and water productivity reached 3.7 kg of grain per cubic meter of water.

The Egyptian Government has endorsed and disseminated a technology package developed at a benchmark research site. Three development projects and more than 1000 farmers in the Middle Delta area using the package have reduced water consumption by 30% and labor costs by 35%, with no reduction in crop yields. Farmers have increased net return per unit of water by 20% and net income by 15%. The Ministry of Agriculture is now recommending that the package – featuring raised bed planting and widely spaced irrigation furrows – should be used in a new 40,000 ha project.

As demand for freshwater increases, the need to find ways of using alternative kinds of water grows. One of these is urban wastewater, but this poses concerns about health and food safety and environmental degradation. ICARDA and the International Water Management Institute (IWMI) are examining the trade-offs in using wastewater and developing low-cost technologies to minimize problem. This will help policymakers make informed decisions when planning water treatment investments and drawing up regulations for using treated wastewater in irrigation.

Sustainable land management

ICARDA has helped to successfully introduce an accurate, quick and non-destructive method for monitoring rangeland degradation in several countries. The new technique, known as Digital Vegetation Charting (DVC), was developed by Oregon State University in the USA. It combines ground-based digital photography, global positioning, and satellite or high-altitude aerial photography to monitor changes in vegetation, plant debris and soil parameters.

DVC is a good estimator of aboveground vegetation cover,

which is the main factor in assessing rangeland health and has several advantages over conventional methods. In particular, it is objective, rapid, non-destructive, captures details and can be repeated in time and space. Numerous requests from National Agricultural Research Systems (NARS) and scientists in other ICARDA programs for the software and training are being processed.

In Iraq and Syria, an Australian-funded project is helping to scale out conservation agriculture techniques. The new methods have been adopted by farmers on more than 10,000 ha. ICARDA and local manufacturers worked together to design and make cheap zero-till seeders to remedy the lack of suitable equipment. Government agencies and NGOs in both countries are now making the seeders available to farmers and, in some cases, are offering micro-credit to help farmers buy them.



A low-cost zero-till seeder, developed by an Australia-ICARDA team in partnership with Syrian entrepreneurs

Livestock and livelihoods

Sheep and goats are a critical part of the production system in dry areas – they are adaptable, easy-to-maintain species well suited to marginal environments. With support from the International Fund for Agricultural Development (IFAD), ICARDA scientists have helped more than 300 families in Syria grow new forage legumes for their flocks and adopt better feeding methods. In Ethiopia, an innovative community-based breeding program, supported by Austria, is helping to improve productivity in four indigenous sheep breeds. The program involves nearly 500 households and 10,000 sheep.

A socio-economic study of resource-poor households covering several countries in West Asia and North Africa revealed a preference for investing in small ruminants. The study identified ways in which policy makers could help small-scale livestock producers improve animal husbandry and produce value-added products, thus making more from their investments.

For rural livelihoods to improve, agriculture must be profitable. ICARDA researchers are studying



In Tunisia, value-added products, such as mint, are creating new sources of income for farmers

the value chains of key commodities in order to create new income opportunities through diversification of crop and livestock production. For example, in six Arabian Peninsula countries, research on date palm covering post-harvest handling and processing methods, better crop management, and integrated pest management techniques has helped improve productivity and quality and boosted profits. ICARDA is now training national scientists to use biotechnology tools to identify and develop better date palm varieties faster and more efficiently.

An IFAD-funded project in Egypt and Morocco studied production and marketing systems along the value chain for olive, pomegranate, and onion. The study identified

major constraints on productivity and expansion, as well as specific policy support measures that would allow small-scale farmers to access highly profitable export markets.

Delivering technology packages

ICARDA researchers help farmers to use technology packages that are practical and cost-effective. In Balochistan province in Pakistan, they worked with FAO, the Arid Zone Research Center, the Agricultural Research Institute, and the Institute of Technology Transfer to introduce wheat varieties tolerant to drought and frost, two of the biggest production constraints in the region. Farmers have adopted crop management packages for five varieties, increasing yields by 35% and gross margins by up to 39%. Community-based enterprises are producing and selling high-quality seed of the new varieties, while farmers and extension agents are benefiting from training programs.

Research for development

Poor households need to make the transition from subsistence to market-oriented production in order for countries to develop. In Syria, research on barley fertilization helped change national fertilizer allocation policies, generating significant benefits in food security, income, and resource productivity. Another study, funded by Canada's International Development Research Centre (IDRC), provided insights into the impact of migration. On one hand, migration by men – and the subsequent remittance flows – could lead to greater investment in new farming technologies. But lack of land titles discourages such



Research on integrated crop-livestock systems is helping to create better livelihoods in dry areas

Highlights of the Year

investment, and women household heads have little control over resources. The study recommended policies that would address the needs of poor women farmers in rural communities with high migration rates.

ICARDA is also using geographical information systems (GIS) techniques to help target research and donor investment more effectively. For example, a poverty assessment and mapping study has helped identify areas in southern Sudan endowed with good natural resources where government and donor interventions would be more effective in alleviating poverty.

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 2009 ICARDA expanded its work in both Africa and Asia. The new office in Ethiopia, opened in October, will play a key role in strengthening collaboration in sub-Saharan Africa.

"There is a bond of togetherness between Ethiopia and ICARDA. Together, we have developed technologies that have improved both quality and productivity ... We call upon ICARDA to fully stand with us and help in training Ethiopian scientists, provide germplasm and breeding lines, and identify and introduce technologies suitable for dry regions."

H.E. Dr Abera Deressa, State Minister of Agriculture and Rural Development, Ethiopia



IFAD partners on a visit to ICARDA discuss how GIS tools can help scale out new technologies faster

Moitree (Friendship)

This new lentil variety for areas with a short growing season is an example of partnership in action. A truly international effort, Moitree was developed by Indian plant breeders from a segregating population which was developed at ICARDA headquarters by crossing a Pakistani landrace with a Bangladeshi breeding line. Progenies from the cross were sent to national research centers in Bangladesh, Ethiopia, India, and Nepal. In India, scientists at the Pulses and Oilseeds Research Station in Berhampore, West Bengal, tested the progenies for several seasons before recommending Moitree for release.

Moitree yields were 50% higher than those of existing varieties in on-station trials and, on farmers' fields, yielded on average 1.15 t/ha, compared with 0.83 t/ha from the highest yielding check variety. Moitree is adapted to a wide range of environments and combines early maturity with resistance to two major diseases.

"Moitree is a blessing ... for the first time we can get steady yields from lentil."

Farmer planning to double the area planted to lentil

In China, the new Center of Excellence for Dryland Agriculture, established jointly by the Chinese Academy of Agricultural Sciences, ICARDA and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), was inaugurated in August. Research will cover several themes: crop improvement and climate change,

water and land management, watershed management, livestock and rangeland systems, and socio-economic and policy analysis. Each theme will include a capacity development program, under which young Chinese scientists will undergo training at ICARDA and other international research centers.

Highlights of the Year



H.E. Matia Chowdhury (center), Bangladesh's Minister of Agriculture, was honored for her work in supporting research-for-development

A new agreement is signed, expanding the long-standing partnership between the Ethiopian Ministry of Agriculture and ICARDA

"ICARDA, ICRISAT and the Ministry have worked together for over two decades ... You have made major contributions to development in China ... I am confident the new Center will produce strong science as well as strong partnerships."

Yao Xiangjun, Deputy Director General, International Cooperation Department, Ministry of Agriculture, China



The new Center of Excellence for Dryland Agriculture was inaugurated in Beijing, China

In Bangladesh, the Minister for Agriculture outlined plans for collaborative research with ICARDA on lentil, chickpea, grasspea, and mung bean ICARDA will provide germplasm, technical support, and training for young scientists.

ICARDA's partners on partnerships

"ICARDA is a recognized Center of Excellence, and is successfully applying the latest science to strengthen agricultural development not only in Syria but throughout the world's dry areas."

H.E. Engineer Mohamed Naji Otri, Prime Minister of Syria

"About 65% of Bangladesh's lentil area is now covered by improved varieties developed through joint research with ICARDA ... we need to strengthen our collaboration in other crops as well. I am confident that with ICARDA's support, Bangladesh will be able to achieve food security for its people."

H.E. Matia Chowdhury, Minister of Agriculture, Bangladesh

"ICARDA has extremely high standards of research, and we would like to benefit from your expertise in improving crop productivity in Eritrea. Your participatory breeding methods are an excellent model for developing countries to follow."

H.E. Ato Arefaine Berhe, Minister of Agriculture, Eritrea

"ICARDA has always been a strong partner with our Ministry ... we wish to further strengthen collaboration to tackle emerging problems relating to soil salinity and associated issues. We are also keen on collaborating on GIS-aided land-use maps, agricultural extension, integrated pest management, biotechnology (tissue culture), water harvesting, and management of small ruminants."

H.E. Dr Mahdi al-Qaisi, Deputy Minister of Agriculture, Iraq

"ICARDA is a unifying force within the region, providing scientific leadership and training, and linking national research programs into the global scientific community ... We feel at home when we are at ICARDA."

Dr Mahmud Duwayri, former Minister of Agriculture, Jordan

"ICARDA is a key strategic partner for Morocco, and I say this very strongly. For example, the land suitability maps prepared by an INRA-ICARDA team are the starting point for all projects under the government-funded Green Morocco Plan."

Prof. Mohamed Badraoui, Director General, INRA, Morocco

Highlights of the Year

In India, discussions with the Central Arid Zone Research Institute and the National Rainfed Rainfed Area Authority identified a number of areas where collaboration could be expanded: small ruminant production, feed resources, rangeland management, water management, and production of legume crops during the fallow period in rice production systems. Speaking at an international conference, H.E. Sharad Pawar, India's Minister of Agriculture, and Dr Mangala Rai, Director General, Indian Council of Agricultural Research, commended ICARDA's strong partnerships with national research systems in India and elsewhere in South Asia.

Presentation Day

ICARDA's research portfolio is continually reviewed and fine-tuned through consultations within the Center and with our partners. In 2009, guest speakers examined pressing global issues on Presentation Day, while the second Science Week brought together ICARDA's partners from 35 countries to share research

results and lessons learnt and to examine how to speed up the adoption of new technologies.

Dr Mahmoud Solh, ICARDA Director General, started Presentation Day by outlining a research-for-development framework that could help developing countries ensure food security and sustainable development in the face of current massive global challenges.

"The key issue is partnerships ... The problems are too large for any one institution or country to tackle. We must work together to apply science to help smallholder farmers adapt to climate change, manage natural resources more sustainably, and create better livelihoods for the poor."

Dr Mahmoud Solh, ICARDA Director General

Guest speakers addressed globally important issues. Dr Rodney Cooke, Director of IFAD's Technical Advisory Division, outlined potential responses to food-related, environmental, financial and other crises faced by developing countries. Dr Mahendra Shah, Coordinator of UN Relations at the

International Institute for Applied Systems Analysis, examined current climate-change models and the projected impacts on agriculture, stressing that although global discussions on climate change focus on mitigation, adaptation is more important – and far more urgent, especially in developing countries.

Guests at Presentation Day included the Prime Minister of Syria; Ministers of Agriculture from Bangladesh, Eritrea and Jordan; Deputy Ministers of Agriculture from Afghanistan, Iraq, Sudan and UAE; heads of national agricultural research systems and others.

Science Week

The theme of Science Week, held at ICARDA headquarters in October, was *Science impact through the research-for-development continuum*. Discussions covered the role of the Center's regional programs in sharing technologies and facilitating collaboration among national agricultural research systems.



Presentation Day in May 2009 was an opportunity for ICARDA and its partners to chart a course for the future

Building capacity

Capacity development is a crucial part of ICARDA's work. During the year, 639 researchers from 41 countries benefited from training internship opportunities. Sixty graduate students were conducting thesis research at various ICARDA research stations; 16 of them completed their MSc or PhD degrees in 2009. Nearly one-fourth of the participants in the capacity development program were women.

Training programs are tailored to the needs of our partners, particularly national research centers in developing countries. Courses covered various areas, including water management, crop improvement, biotechnology, seed production, integrated crop-livestock management, socio-economics, information technology, and research-station management. New topics are continually introduced in response to new challenges: for example, training was offered in pathotype analysis of stem rust variants and in molecular characterization methods for livestock breeds.

Linking research to development

In January 2009, IFAD and ICARDA agreed on a framework for linking strategic research with existing IFAD development projects in the Near East and North Africa. The intention is to speed up dissemination of new technologies. A few months later, in May, ICARDA signed a similar agreement for rural development projects with the Islamic Development Bank.



Dr Mohamed Ali (left), President of the Islamic Development Bank, and Dr Mahmoud Solh, ICARDA Director General, signed a new agreement scaling up support for collaborative research

During the year ICARDA also met with major development agencies – the Arab Fund for Economic and Social Development (AFESD), the Islamic Development Bank, the Kuwait Fund for Arab Economic Development, and the Saudi Fund for Development – to discuss research–development linkages.

"The Arab Fund is happy to work with ICARDA ... We must ensure that every development project we fund contains a research component, and we urge other agencies in the region to build this approach into their funding plans."

Dr Ahmed Osman, Director, Technical Department, Arab Fund for Economic and Social Development

In Egypt, this approach of linking research with development has had spectacular results. The Egyptian Government, with funding from IFAD, is putting into practice technologies to improve water productivity developed by ICARDA and national partners in a US\$6 billion, two-million hectare development project.

New initiatives

Major initiatives in research-for-development were launched in 2009.

Egypt's Agricultural Research Center (ARC) and ICARDA announced plans for a new 10-year, joint wheat research program. It aims to develop wheat for irrigated agriculture that will yield 30% more grain and have better resistance to diseases than current varieties.

The Japan International Cooperation Agency (JICA), ICARDA, and the Government of Syria signed a five-year agreement under which JICA will fund a range of training programs. Designed for research and extension staff from developing countries, the programs cover crop and seed production and sheep and goat husbandry.

To understand how different climate change scenarios could affect crop yields, resource use and farm incomes, the Asian Development Bank funded a new project on the impact of climate change on rural livelihoods in Central Asia and China. The project uses GIS tools, crop simulation models, and socio-economic analysis.



Akiko Tomito (left), JICA's Chief Representative in Syria, and Dr Maarten van Ginkel, ICARDA's Deputy Director General for Research, sign a new agreement on training programs

Prime Minister of Syria visits ICARDA

The Prime Minister of Syria, H.E. Eng. Mohamed Naji Otri, accompanied by the Syrian Minister of Agriculture, H.E. Dr Adel Safar, the Minister of Irrigation, H.E. Nader Al Boni, the Head of the State Planning Commission, H.E. Tayssir Raddawi, and the Governor of Aleppo, H.E. Eng. Ali Ahmad Mansoura, visited ICARDA headquarters in May 2009.

The Prime Minister expressed great interest in the Center's work, especially biocontrol methods to combat insect pests, and the use of GIS tools for land-use planning and analysis of cropping patterns. Discussing a research project on agro-ecological zoning being conducted jointly by ICARDA and Syria's General Commission for Scientific Agricultural Research, he said the findings would help national policy makers to better match crops to particular environments.

"ICARDA has the full support of the Syrian government," the Prime Minister said. "The Syrian national program will continue to work closely with ICARDA for national as well as regional benefit."



H.E. Eng. Mohamed Naji Otri (second from right), Prime Minister of Syria, visited field experiments and laboratories at ICARDA headquarters

The Coca-Cola Foundation funded two new projects. One focuses on safe and effective ways of using domestic wastewater for small-scale agriculture and market gardening in Syria. The other promotes soil and water conservation in mountainous areas of Palestine, Jordan, and Lebanon, where intensive olive cultivation on steep slopes has caused severe erosion.

Austrian agencies are supporting a three-year project in the Ethiopian highlands to integrate land and water management. Conservation agriculture, rainwater harvesting, supplemental irrigation and improved varieties will increase yields and improve the sustainability of rainfed farming systems.

IFAD funded a new four-year project in Iraq to improve the productivity of two major crops – wheat and date palm. The project tests and promotes integrated pest management and more effective use of organic fertilizer.

International Awards

Dr Mahmoud Solh, ICARDA Director General, won the Lifetime Achievement Award, instituted by the Indian Society of Pulses Research and Development, for his "outstanding contribution in promotion of grain legumes globally". Dr Solh received the award in February 2009, from Dr A.P.J. Abdul Kalam, former President of India. Dr Solh also won the International PNASF Gold Medal Award for his contributions to promoting agricultural science. The medal, from the Prem Nath Agricultural Science Foundation (PNASF), was presented to him in November 2009 in Bangalore, India.



Dr Abdul Kalam (right), former President of India, presents the Lifetime Achievement Award to Dr Solh

Dr Miloudi Nachit, Dr Mustapha El Bouhssini. A joint Morocco-ICARDA team won the 2009 Hassan II Grand Prize for Invention and Research for their work on durum wheat. Three institutions were involved: the Institut National de la Recherche Agronomique (INRA), L'Institut Agronomique et Vétérinaire Hassan II and ICARDA. Two ICARDA scientists – Senior Durum Wheat Breeder Dr Miloudi Nachit and Senior Entomologist Dr Mustapha El Bouhssini – were part of the team.

Dr Ahmed Amri, Head, Genetic Resources Section, received a

special award from Iran's Dryland Agricultural Research Institute (DARI) for his contributions during the four years he spent as Coordinator of ICARDA's Iran office. The award was given at a ceremony organized by DARI in Maragheh, Iran, in February 2009.



Dr Rajinder Malhotra (in turban), honored for long-term contributions to legume research

Dr Rajinder Malhotra, Senior Chickpea Breeder, received a gold medal from the Indian Society of Pulses Research and Development, presented to him by Dr Abdul Kalam, former President of India, in February 2009. The citation mentions some of his contributions to plant breeding, training and other areas. In July, at the International Ascochyta Workshop held in the USA, he won the Meritorious Service Award for "excellence in breeding ascochyta blight resistant germplasm and varieties of chickpea".

Dr R.S. Paroda, formerly ICARDA's ADG for International Cooperation,



Dr Raj Paroda (right) receives the award from Somnath Chatterjee, Speaker of the Indian Parliament

received a Lifetime Achievement Award in September 2009. Excerpts from the award citation: "Significant contributions to strengthening the national agricultural research system in India as well as in Central Asian countries and the Caucasus ... a geneticist of international repute ... the main architect of the world's three largest and most modern national genebanks."

Dr Michael Baum, Coordinator – Biotechnology, was named Guest Professor at Ghuangzhou University, China, for the next three years. The award was announced by the university in October 2009.

Dr Maarten van Ginkel, Deputy Director General – Research, was honored twice by the Crop Science Society of America at their annual meeting in Pittsburgh, USA, in November 2009. He was named Fellow of the Society and also won the International Service in Crop Science Award.

Dr John Ryan, Soil Scientist, was named Fellow of the Crop Science Society of America at the Society's annual meeting in Pittsburgh in November 2009. He is the only scientist ever to receive both categories of award (Fellow and International) in all three of the Society's disciplines: soil science, agronomy, and crop science. In January 2009, Dr Ryan also received the 2008 Science Award from the International Plant Nutrition Institute "in recognition of outstanding achievements in research and education".

Staff of the Year

Each year, ICARDA gives Staff of the Year awards to outstanding individuals and teams under various categories. This year's winners – recognized for performance in 2009 – received their awards from Mr Henri Carsalade, Board Chair, and Dr Mahmoud Solh, Director General.



GS-level (Administration):
Mr Mustafa Abaza, Liaison Assistant, Nile Valley and sub-Saharan Africa Regional Program

Outstanding Research Team: Women's Livelihood and Dairy Goat Project team – staff from ICARDA, national research programs in Afghanistan and Pakistan, and NGOs in both countries

Outstanding Service Support Team: Finance department



P-level (Research):
Dr Francis Ogbonnaya, Bread Wheat Breeder/Biotechnologist



P-level (Research administration):
Dr Ashutosh Sarker, Coordinator, South Asia and China Regional Program



GS-level (Research):
Ms Layal Attasi, Data Management Assistant, GIS Unit; and Mr Mohamed Haylani, Research Technician, DSIPS



GS-level (Technical):
Ms Nahla Assal, Accountant



Outstanding Scientific Article: written by a multi-disciplinary, multi-institution team. Asymmetric allele-specific expression in relation to development variation and drought stress in barley hybrids, by Maria von Korff, Slobodanka Radovic, Wafaa Choumane, Konstantina Stamati, Sripada Udupa, Stefania Grando, Salvatore Ceccarelli, Ian Mackay, Wayne Powell, Michael Baum and Michele Morgante. Published in The Plant Journal, vol. 59.



The Dairy Goat Project team with Director General Dr Solh



The Finance team at Tel Hadya

Research Portfolio

ICARDA's research portfolio is positioned to address both existing and emerging problems. Its programs span the entire continuum of research-for-development, which ensures that outputs are relevant and can be used efficiently for the benefit of resource-poor farming communities in non-tropical dry areas.

This portfolio builds on ICARDA's three decades of experience in the dry areas of developing countries. It is based on the 10-year Strategic Plan, adopted in 2008, which re-oriented the Center's research to better address climate change, food insecurity, desertification, and other challenges in dryland areas.

All ICARDA's research is planned and implemented in collaboration with national agricultural research systems (NARS), working through a network of country offices and seven regional programs. These programs are:

- 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 and China Regional Program
- Highland Regional Network, serving Afghanistan, Pakistan, Iran, and Turkey.

The Center has four thematic research programs, as outlined below.

Biodiversity and Integrated Gene Management

This program aims to conserve the biodiversity of globally important crop species originating in dry areas, and to use these resources to improve food security, nutrition and livelihoods. Research focuses on conservation, characterization, and evaluation of genetic resources of bread and durum wheat, barley, chickpea, lentil, faba bean, and forage and pasture crops; germplasm enhancement, using both conventional methods and new biotechnology tools; integrated

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 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. Research includes poverty analysis and mapping to identify pathways out of poverty; value chain and market analysis; and policy and institutional options to improve livelihoods. Other key components focus on identifying barriers to the adoption of new technologies, and assessing the impacts of the Center's research.

Biodiversity and Integrated Gene Management



Summary of achievements

The main achievements of the Biodiversity and Integrated Gene Management Program in 2009 include:

- The barley variety Yundamai 2, developed from ICARDA germplasm, gave the highest yield ever recorded in China. In Ethiopia, 35,000 farmers planted MisCal21, a barley variety developed jointly with local partners.
- Ongoing work in the new ICARDA biosafety facility focused on genetic engineering methods to improve drought tolerance and fungal disease resistance.
- Haplotype analysis revealed that many of ICARDA's elite bread wheat lines contain a gene giving resistance to Ug99, a dangerous new race of stem rust. DNA-based race analysis has shed light on the genetics that caused a stripe rust epidemic in wheat.
- Tests showed that a fungal isolate was highly effective in killing adults of the Sunn pest (an important pest of wheat) without harming the pest's natural enemies.
- Field surveys revealed that the chlorotic stunt virus of chickpea, earlier reported only from specific regions, in fact occurs in many countries.
- Two new varieties of kabuli chickpea, developed from ICARDA material, are rapidly replacing traditional varieties in the Ethiopian highlands. Both are high-yielding, resistant to multiple diseases, and fetch premium prices.
- The program identified several new sources of resistance in lentil, and two grass pea genotypes with very low levels (0.15 to 0.2%) of the neurotoxin ODAP. These are being distributed to national plant breeding programs.



Isolation cages installed at the Tel Hadya research station to regenerate cross-pollinated species

Genetic resources: at the core of food and agriculture

In 2009, ICARDA's Genetic Resources Section (GRS) continued its work on improving genetic resources to sustain agricultural development. It added to the genebank around 1700 accessions, including 382 obtained from joint collections in Jordan, Libya, Syria, and Yemen. This brought the total holdings to more than 134,000. GRS sent two shipments totaling 63,787 accessions to the Svalbard Seed Vault in Norway for long-term conservation, and distributed more than 20,000 accessions to partners worldwide.

Eight sets of these accessions were created using the Focused Identification of Germplasm Strategy (FIGS). FIGS creates 'best-bet' subsets of material, by passing information on accessions, like the soil type and climate where they were collected, through a series of filters that raise the chances of researchers finding a particular trait. The eight 'best bet' sets created during 2009 targeted drought, frost and disease resistance, as well as low levels of ODAP, a toxin present in grasspea that can cause a neurological disease known as lathyrism.

GRS planted more than 21,500 accessions for characterization, regeneration, and evaluation. It has developed more than 100 isolation cages for the regeneration of cross-pollinated and self-incompatible species and evaluated more than 6500 cereal

accessions for stripe rust resistance. GRS also continued its pre-breeding activities, by making more than 270 interspecific crosses and backcrosses for bread wheat and durum wheat improvement.

Support for partners was another important activity. In Yemen, GRS provided technical backstopping to promote on-farm conservation and informal seed production of landraces. And it lent its expertise to Moroccan, Tunisian, and Yemeni genebanks on best practices and documentation, and to Kuwait and Iran-Karaj University on establishing genebanks.

GRS collaborated with the Food and Agriculture Organization's (FAO) Near East and North Africa Division to assess plant genetic resources for food and agriculture (PGRFA) as a contribution to the Second Report on the State of the World's PGRFA. It also carried out a SWOT analysis of PGRFA conservation activities in countries of Central Asia and the Caucasus (CAC), and an in-depth assessment of genebanks in Tajikistan, Yemen, and Georgia.

ICARDA's GRS organized a series of training courses for the benefit of 18 NARS scientists from seven countries. In addition, support was provided to three BSc and two MSc students, and one PhD student.

Biotechnology

ICARDA's biotechnology activities support researchers with technologies such as tissue culture, DNA markers, and genetic engineering. During 2009, ICARDA established a biosafety facility enabling the safe testing of transgenic plants. ICARDA geneticists developed transgenic



ICARDA's genebank plays many roles: protecting biodiversity, discovering new sources of stress-resistance genes, and building national capacity through training programs and collaborative research

wheat and barley using *Agrobacterium*-mediated transformation into immature embryos, as they had already done in chickpea and lentil. *Agrobacterium* was used because it efficiently delivers large DNA segments into plants.

ICARDA also developed two TILLING ('targeted induced local lesions in genomes') wheat populations for use in reverse and forward genetics screening. Reverse genetics allows the selection of variant genes thought to control desirable traits. TILLING lines produce a perfect molecular marker and can be used in breeding programs as they are not genetically modified organisms.

Other ICARDA scientists evaluated lentil and faba bean wild accessions for salinity tolerance to better understand how resistance is inherited. Other biotechnology activities included designing more than 1000 simple sequence repeat (SSR) markers from the genomic sequence of the date palm for genome analysis.

ICARDA also provided biotechnology training. Scientists delivered a training course on DNA markers and genetic engineering in Syria, a training course on biotechnology in Oman, and a workshop on GMO detection and biosafety in Iran.

Species cross-breeding drives sustainable wheat improvement

Cross-breeding between wild wheat species at ICARDA's dryland research stations has created germplasm that produces higher yields under the stress of extreme drought. For the wide crosses (crosses between species of the same or different genera), the parental material came from ICARDA's genebank, which collects and conserves wild relatives and landraces for the genetic improvement of cultivated wheat and barley.

The genebank now holds almost 4000 accessions of *Aegilops* species, 1587 wild *Triticum* species and 857 accessions of primitive wheat species, making it one of the richest holdings in the world.

The crossing program

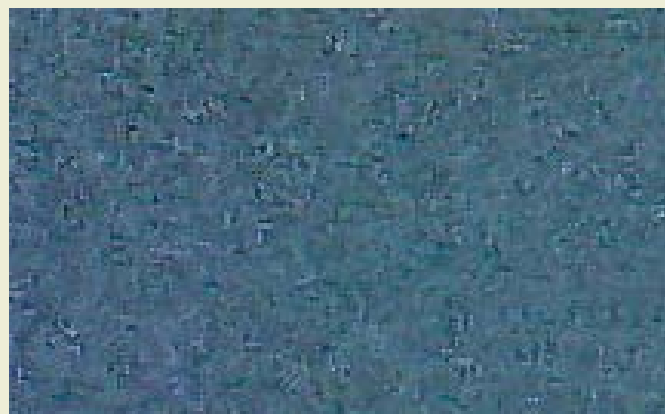
Since 1993, ICARDA's Genetic Resources Section has been crossing species and genera from the genebank to enlarge the genetic base of cultivated species. More than 350 crosses and backcrosses are made annually as part of pre-breeding activities.

The section had one notable advance when crosses made with *Triticum urartu*, *T. dicoccoides*, *T. boeoticum*, *Aegilops tauschii* and *Ae. speltoides* were found to have better resistance than their parents to the fungal diseases stripe rust, stem rust and *Septoria* leaf blotch and to the insect pests Russian wheat aphid and Hessian fly. Many promising lines also showed good tolerance to drought (less than 180 mm of rain annually) at ICARDA's Breda research station.

The next step was to use the wild wheat species and the landraces to strengthen bread wheat and durum wheat to help them resist drought, heat, and the new and more virulent forms of disease that may develop as a result of climate change.

Improved grain quality and drought tolerance

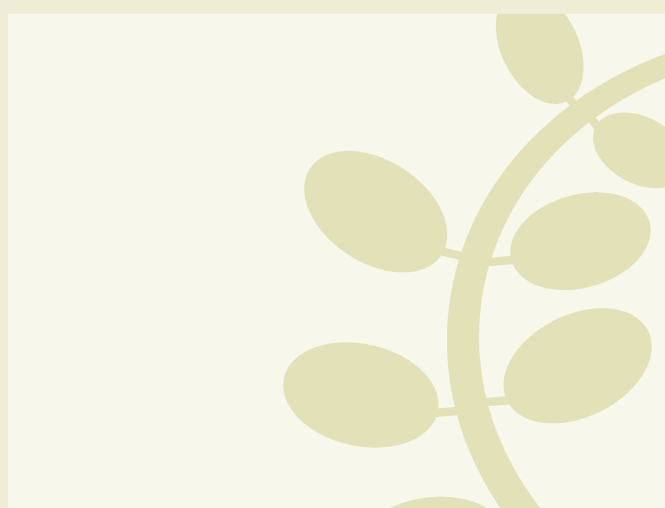
The wild species and landraces have also been used to improve grain quality. For example, since the 1980s, plant breeders have crossed *Ae. tauschii* (an important ancestor of bread wheat) with durum wheat to widen the genetic diversity and made available several new and valuable genes for bread wheat improvement.



Cross-breeding with wild species to produce synthetic wheat: left to right; *Triticum boeoticum* (wild parent), first-generation cross, and durum wheat (cultivated parent)

Two hundred accessions of the wild wheat species *Ae. tauschii* and three accessions of *Ae. vavilovii* were evaluated for drought tolerance between 2007 and 2009. In the severe drought of 2007-08, accessions of both species originating in Pakistan and Afghanistan showed higher tillering capacity and better tolerance to drought than other accessions. These drought-tolerant accessions were then used in crosses with bread wheat and durum wheat.

Clearly, ICARDA's work is contributing to the better use of global plant genetic resources and the development and sharing of improved germplasm for farmers in dry areas worldwide.



Conserving agro-biodiversity in the Fertile Crescent

Genetic resources play a key role in agricultural development and the drive for food security. They provide novel genes to fight the stresses to which crops are vulnerable, both biological, such as pests, and non-biological, such as drought. They are a strategic asset in adapting to climate change and they can be used to rehabilitate degraded ecosystems.

A threatened hotspot of biodiversity

The Fertile Crescent is one of the world's biggest biodiversity hotspots. It is a globally important center of crop diversity, and the center of origin and domestication of wheat, barley, lentil, faba bean, many feed legumes (*Vicia*, *Medicago*, *Pisum*, *Lathyrus* and *Trifolium*), and more than seven genera of fruit trees, including olive, pistachio, almond, and fig.

Landraces of these crops are still used in the traditional farming systems across the countries of CWANA, while their wild relatives grow in the remaining natural habitats. But the degradation of natural ecosystems and the loss of biodiversity in agriculture mean that there is an urgent need for collaborative efforts to ensure their conservation.

Successes, from genebanks to communities

Ever since it was founded, ICARDA has made conservation and sustainable use of agricultural biodiversity in the CWANA region a priority. By December 2009, ICARDA's genebank, set up in 1985, held 134,247 accessions, most of them from the Fertile Crescent.

Few developing countries have genebanks supported by the facilities and technical expertise available at ICARDA. Some do not have genebanks at all. ICARDA plays a crucial role in safeguarding the genetic resources of cereals, food legumes, feed legumes, and rangeland species. ICARDA gives duplicate accessions to the countries where they were found, and distributes more than 20,000 every year for use in breeding, research, and education.

ICARDA also promotes the conservation of agricultural biodiversity *in situ*. A good example is the



Collection missions have been conducted in several countries across the Fertile Crescent, helping to protect its unique diversity of food crops, trees and vegetables

regional project implemented in Jordan, Lebanon, Syria, and Palestine that promoted community-driven conservation and sustainable use of agricultural biodiversity in dry areas. The project ran from 1999 to 2005 and was funded by the Global Environment Facility.

From genebanks to new crop varieties

Researchers are constantly looking for novel genetic material to strengthen plant-breeding efforts. But finding the right genetic traits from among tens of thousands of genebank accessions is like looking for a needle in a haystack. ICARDA's Focused Identification of Germplasm Strategy (FIGS) is an innovative tool that allows scientists to quickly search large collections and pinpoint genotypes that are likely to contain the stress-resistance traits essential for developing new varieties for dry areas.

The vital role that native pasture species, landraces and wild relatives can play in rehabilitating degraded drylands and developing improved varieties is beyond doubt. But more effort is needed to enhance national capacities and strengthen regional and international collaboration. ICARDA will continue to play a key role in achieving these goals and in training scientists and farmers to apply its discoveries in the field.

Improving wheat varieties

In 2009, ICARDA's spring bread wheat breeding program sent seven sets of elite breeding lines to 52 collaborators in 29 countries. These sets represented a range of promising breeding material for a wide range of environments that include hot and very dry areas, as well as more favorable ones. ICARDA's partner organizations will further test the best lines in these locations. To combat the alarming threat of the Ug99 race of stem rust to wheat-based production systems in CWANA, two of the trials included lines resistant to Ug99.

At ICARDA's Tel Hadya station, plant breeders checked 480 elite bread wheat lines for the presence of nine stem-rust resistance genes using two highly specific molecular techniques. At least half of the lines have the *Sr2* gene, which significantly slows the disease's progression.

Importantly, this suggests that ICARDA's latest breeding lines

already have some resistance to race Ug99.

Researchers also characterized heat and drought tolerance of parents of four genetic mapping populations using 328 specific genetic sequences from the existing bread wheat consensus map. Some sequences differentiated between plant types, so scientists are now using these sequences to map the four populations for traits conferring heat and drought tolerance, confirming their presence and providing genetic information to aid future breeding.

Other ICARDA research focused on durum wheat. Plant breeders selected from early-stage populations and advanced lines to improve resistance to stem and leaf rusts in Lebanon and Ethiopia, and heat tolerance and resistance to dryland root rots in Syria. In addition, ICARDA planted early-stage populations, nurseries, and trials at nine research stations in four countries for the 2009/2010 season, so breeders could identify

the best lines for further improvement or wider testing.

The environments of the nine locations used represent the range of stresses and conditions in the CWANA areas where most durum wheat is grown. Breeders selected for a number of characteristics. In Syria, they targeted early planting for cold tolerance and normal planting for continental areas, drought tolerance, yield potential and *Septoria* resistance. In Lebanon, they bred for cold tolerance, yield potential, and tolerance to extreme temperatures, and in Egypt for yield potential and adaptation to the Nile Valley. In Morocco, breeders focused on resistance to stem rust, suitability for zero tillage, adaptation to North African environments, and resistance to Hessian fly and *Septoria* leaf blotch.



Farmers participate actively in the process of testing and selecting new varieties

Combating a new global pathogen of wheat

Global production of wheat – a staple food for more than two billion people – is threatened by rust diseases spread by wind-borne spores. A virulent race of stem rust, Ug99, poses a new threat. It was discovered in Uganda in 1999, hence the name, but has now spread to the Arabian Peninsula and West Asia. Experts predict it is only a matter of time before Ug99 reaches South Asia – potentially devastating crops in the world's most populous region and threatening the food supplies of more than one billion people.

Working together

ICARDA and the International Maize and Wheat Improvement Center (CIMMYT) have joined forces with national research centers to combat rust diseases. A new project for the accelerated seed multiplication of varieties potentially resistant to wheat rusts, particularly Ug99, has been approved by USAID.

The project builds on previous work by ICARDA, CIMMYT and national research centers in several African and Asian countries. It targets Afghanistan, Bangladesh, Egypt, Ethiopia, Nepal, and Pakistan and focuses on four key components: (i) it identifies varieties resistant to Ug99 and other major rust diseases in the target countries; (ii) it facilitates fast-track testing and release of these varieties in collaboration with partners; (iii) it provides information and training to farmers on resistant varieties and crop management practices; (iv) it puts in place accelerated pre-release and large-scale (certified) seed multiplication for distribution to farmers.

The main objective of the project is to replace existing rust-susceptible varieties as quickly as possible – to minimize the time from when potentially resistant varieties are identified to when they are made available to farmers for use in their fields.

The project achieves this through accelerated seed multiplication and dissemination in collaboration with NARS, national seed programs and farmers. ICARDA, working with local partner NARS, has already started



Intensive international collaboration has helped identify several wheat lines resistant to Ug99 stem rust

pre-release accelerated seed multiplication in Egypt, Ethiopia and Pakistan.

Getting seed out to farmers

In Egypt, in addition to testing and demonstrating Ug99-resistant lines, the team has multiplied the seed of six advanced lines. They have also identified two varieties (Misr 1 and 2) that combine high yield potential and resistance to Ug99 and the three local rusts. Both varieties have been recommended for release in Egypt. The national seed program has produced more than 22 tons of these varieties for large-scale seed multiplication and demonstration. During 2009/10, the program will produce 405 tons of seed for further multiplication and possible commercialization in 2010/11.

In Ethiopia, researchers multiplied five promising lines (Chonte 1, Danphe 1, Munal 1, Picaflor 1, and Quaiu 1) and three lines from ICARDA (Amir, Flag 3, and Flag 5) during the main season. This will be followed by off-season seed multiplication.

In Pakistan, the Pakistan Agricultural Research Council and the private seed sector multiplied three varieties: Chonte 1, Munal 1, and Quaiu 1, but they proved to be susceptible to local rust races. Several promising replacement lines will be multiplied in 2009/10.

Barley: working with farmers to produce new varieties

During 2009, ICARDA continued working with farmers in Syria to identify types of barley well-suited to local conditions. In the very dry areas, farmers' yields of these varieties were 0.4 to 0.5 t/ha, which was 25 to 30% more than the local landrace and 19 to 25% more than the improved variety Zanbaka. In the wetter areas, average yields were 1.0 to 2.6 t/ha: 5 to 80% more than the local landrace and 3 to 26% more than the improved variety Furat 2.

A survey in Aleppo province in Syria found that in Kherbet El Dieb village, where participatory plant breeding (PPB) began five years ago, three varieties (Harmal, Zanbaka, and Zahra) were planted on 50% of the village's total barley area (about 4000 hectares). In Kherbet Shlash village, new to the PPB program, 1000 hectares were planted with the new variety Nawaair 1, originally selected in Hama province. A survey in Hama province covering five villages where barley is grown on 30% of the total area planted with annual crops, found that no less than 90% is planted with ICARDA varieties Arta, Suran 1, Suran 2, Nawaair 1, and Nawaair 2.

Participatory breeding trials in Iran have expanded to include nine villages in Kermanshah province (an important cereal production area) and nine villages in Semnan province. Farmers are growing a barley evolutionary population which is also grown in Qazvin, Chahar Mahal, and Bakhtiari provinces. In irrigated areas and in Kermanshah province, a project was started in 2009 on 'Participatory Evaluation of

Germplasm Collections' with the support the Global Crop Diversity Trust.

The variety Yundamai 2, based on ICARDA germplasm, is rapidly expanding in Yunnan province, China. The Yunnan Academy of Agricultural Sciences is very active in multiplying the variety in farmers' fields. In 2009, the variety broke the historical barley yield in China with 10.8 t/ha.

In Ethiopia, the variety MisCal21 based on ICARDA germplasm was released in 2006 by the Ethiopian Institute of Agricultural Research (EIAR). Today, it is well accepted by the local malt industry and in 2009 was planted by about 35,000 farmers on about 40,000 hectares.

In Jordan, three new varieties have been identified and nearly 6 tons of quality seed have been produced. In addition, the feed barley variety PL 807 has been released for irrigated conditions in Punjab, India, where it yields an average of 4.3 t/ha.

Reinvigorating faba bean breeding

The faba bean, or broad bean, is an important and cheap source of protein for many dryland communities. ICARDA has a global mandate to improve faba bean, and also houses the largest germplasm collection of the crop. Breeding activities are conducted in cooperation with national agricultural research systems (NARS) around the world. An expanded breeding program was reinitiated in 2008 to support the needs of national programs, focusing on China, the Nile Valley and sub-Saharan Africa. Climatic variability (cold, heat, and drought) and biotic factors

(parasitic weeds and diseases) affect faba bean production and productivity. In the Mediterranean region, the most limiting factor for faba bean production is the parasitic weed broomrape (*Orobanche crenata* and *Orobanche aegyptiaca*). The parasite affects faba bean mainly in low rainfall and marginal lands (Syria, Egypt, Tunisia, Morocco, Spain, and Italy), but as drought becomes a day-to-day phenomenon in major faba bean-producing countries, broomrape is expanding into new areas like Ethiopia. The fungal diseases *Ascochyta* blight (caused by *Ascochyta fabae*) and chocolate spot (caused by *Botrytis fabae*) also limit productivity and production in countries in the Mediterranean region, China, Latin America, Ethiopia, and Australia.

Since 2008, advanced lines resistant to broomrape, chocolate spot, *Ascochyta* blight, cold, and drought have been developed and sent to NARS worldwide for adaptability testing in different environments. Major achievements during 2009 were the identification of new lines with acceptable tolerance to broomrape, and advanced new lines with resistance to chocolate spot and *Ascochyta*; identification of sources of cold tolerance and rust resistance; and the evaluation of breeding lines with a low tannin content that are potentially high-yielding and self-fertile.

Promising results have been obtained from ICARDA's collaboration with partners in Ethiopia, where faba bean is ranked first among highland cool-season food legumes.

Continued on page 22

Diving into the barley genepool

Barley is a hardy crop, producing reliable harvests in areas with poor rainfall and soils. It is also versatile – a major food for millions of people, a key animal feed, and the principal ingredient in beer and other beverages.

ICARDA scientists have studied barley for more than 30 years, developing varieties better adapted to diverse growing conditions and improved techniques now used worldwide. In 2009, they continued innovative work on the genetic diversity and evolution of barley, also using biotechnology.

Assessing genetic diversity

The barley genepool is very diverse, containing tens of thousands of genotypes, many of which are represented in the ICARDA genebank's 25,000 barley accessions.

Together with scientists from Morocco's National Agricultural Research Institute and Southern Cross University in Australia, ICARDA looked at genetic diversity and geographical differentiation in 304 accessions from 29 countries. These included wild barley as well as landraces – local or indigenous varieties grown by farmers for generations.

The scientists found that the barley accessions fell into three distinct germplasm pools: East Africa (Eritrea, Ethiopia) and South America (Ecuador, Peru, Chile) in one group, the Caucasus (Armenia and Georgia) in another, and the rest in a third group. This provided some interesting insights and raised questions about the evolution of barley.

Exploring evolution

For example, in the case of East Africa and South America, why should widely separated traditional varieties be genetically similar? There are two possible answers: either South American landraces originated from East Africa, or the two groups shared common parents at some stage of their evolution.

Landraces from North Africa (Egypt, Libya, Morocco, Tunisia) in the third group were similar to East African landraces. A possible explanation is that



Studies of genetic diversity in barley are helping to unlock evolutionary secrets – and to better target varieties for specific environments

because both regions grow barley for food, selection by generations of farmers gradually led to convergence. But there could be a simpler explanation – generations-old travel, migration, and trade between the two regions.

The most diverse regions in the study were North Africa (especially Morocco), East Asia (the Tibet region of China), and the Near East (the Fertile Crescent). This suggests that barley may have been first domesticated in one of these regions (the primary center), transported by people to another (the secondary center), and later, gradually spread to other parts of the world. Alternatively, it could have been domesticated independently in more than one place – possibly the Fertile Crescent and Tibet.

Another major study, conducted jointly by ICARDA, CIMMYT, and universities in Australia and Mexico, looked at genotype-by-environment interactions in barley. The researchers analyzed 27 years of data from 750 trials in 75 countries to identify 'mega-environments', and within each 'mega-environment', the best locations to breed new barley varieties. Studies like these are providing new insights into crop adaptation and helping to better target new varieties at appropriate environments.

More detailed studies are needed, but one thing is certain: with biotechnology tools becoming cheaper and more accurate, scientists are making very rapid progress in exploring the genetic diversity of barley.

Faba bean breeding continued

For example, between 2006 and 2008, four good quality varieties were developed and officially released that had high yield-potential and were well-adapted to black soil types. They were also tolerant to lodging and resistant to disease. These varieties – Moti, Gebelcho, Obsie, and Walki – were developed from crosses made between local landraces and ICARDA's international public goods (ILB4432, ILB4726, ILB4427, and ILB4615, respectively) and sent to the Ethiopian Institute of Agricultural Research through international nurseries.

In China, a new faba bean variety, Yandou, has been well received since its release in 2004. Yandou was produced by crossing the local variety Ko285 with ICARDA line ILB8047.

Lentil: improving yields and nutrition

Lentil is one of ICARDA's global mandate crops and also an

important source of protein for people in dryland areas. During 2009, ICARDA identified 51 new accessions resistant to *Fusarium* wilt, 12 tolerant to salinity and 6 resistant to heat. The Center developed country-specific crosses (434 F₁) in an attempt to widen lentil's genetic base, particularly for the South Asia and CWANA regions.

ICARDA's lentil improvement program has led to NARS partners releasing six multiple disease-resistant varieties with 30-40% higher yields during 2009. These varieties are Kimiya (FLIP 92-12L) in Iran, Chakkouf (FLIP 96-15L) in Morocco, Maheshwor Bharati (FLIP 96-50L) and Sagun (FLIP 89-71L) in Nepal, and Punjab Masoor and NARC-06-1 in Pakistan.

Zinc and iron deficiencies are major nutritional challenges for the poor in lentil-growing areas. Bio-fortification of lentil cultivars with zinc and iron can help address this problem. In 2009, ICARDA assessed the genetic variability of

zinc and iron contents in lentil germplasm and improved breeding lines. Analysis of 357 accessions revealed wide variation – 18 to 103 milligrams for zinc and 46 to 133 milligrams for iron. One accession of *Lens orientalis*, ILWL 74, was outstanding with 132.5 milligrams of iron.

Breeding vigorous chickpea

ICARDA has been successful in producing types of chickpea that are able to thrive in the harsh ecosystems of dryland areas. In 2009, ICARDA developed 1713 new chickpea lines with resistance to drought, heat and cold. In total, 340 sets of 12 diversified chickpea nurseries were shared with national programs in 40 countries.

Work with NARS partners in Iran identified three ICARDA-developed genotypes which survived a harsh cold environment of -17°C without snow cover. These will be used to develop varieties suitable for the highlands of Iran.

Other ICARDA research focused on chickpea resistance to fungal disease. Scientists selected 3412 (out of 16,595) lines that showed resistance to *Ascochyta* blight disease under field conditions. They also selected 393 (out of 5421) lines that showed resistance to *Fusarium* wilt, a soil-borne disease that is becoming increasingly common due to changing climatic conditions.

Under late spring planting at ICARDA headquarters, scientists selected 968 drought-tolerant lines (out of 2492 lines) as those best suited for dry areas. In addition, researchers used two recombinant inbred populations to tag genes for drought tolerance and *Ascochyta* blight resistance.



New legume varieties developed by ICARDA and its partners are helping to improve yields, incomes and nutrition



Chickpea trial at Tel Hadya: in 2009, ICARDA developed 1713 new chickpea lines with resistance to environmental stresses

ICARDA scientists also identified chickpea lines resistant to leaf miner insect larvae which feed on the narrow leaves of chickpea plants, and incorporated this resistance into otherwise desirable cultivars to fit well into spring planting in CWANA.

Grass pea: reducing toxins

Grass pea (*Lathyrus sativus*), a food and fodder crop, has the potential to withstand the conditions associated with climate change. It is tolerant to drought, water-logging, and salinity, and is practically free from pests and diseases. And grass pea is a legume, so could provide cheap protein for poor communities in dryland areas. However, grass pea remains underused because long-term consumption can lead to paralysis (lathyrism) caused by the neurotoxin ODAP in seedlings and seeds.

In order to develop safe cultivars of grass pea, ICARDA tested ODAP

levels in 1,128 accessions of *Lathyrus sativus* from its own large collection. ODAP contents ranged from 0.15% to 0.95%. Only two accessions fell within the safe limit for human consumption: less than 0.2% ODAP.

However, the closely related wild species, *Lathyrus cicera*, showed more promising results. The ODAP contents of 142 accessions of *L. cicera* ranged from 0.07% to 0.51% and 11 accessions had less than 0.2% ODAP in their seeds. Six selected lines had high yields (more than 1 t/ha) and low ODAP levels (less than 0.1%). ICARDA will share these lines with NARS partners through international nurseries, and will also use the lines to develop well adapted, low-ODAP varieties with NARS.

New IPM options

Although chemical pesticides can control pests in the short term, they also destroy natural predators and induce resistance in

insect pests, so are of limited use over the long term. Integrated pest management (IPM) offers alternative solutions including cultivation techniques, breeding resistant plants, and biological control. ICARDA research on IPM has focused on available options and the population dynamics of pests affecting wheat, barley, and legumes (faba bean, lentil, and kabuli chickpea).

The ICARDA team investigated the effectiveness of insect-killing fungi in controlling Sunn pest, one of the most serious pests of wheat and barley. A Syrian fungus isolate (SPSR2) proved to be pathogenic for Sunn pest adults, but had no negative impact on the natural-enemy parasitoids which attack Sunn pest eggs. That fungus could therefore be used safely as a biological control agent.

ICARDA's research on managing diseases affecting legumes is identifying sources of genetic resistance to the fungal diseases *Ascochyta* blight and chocolate spot, as well as various wilts. The team identified many genotypes with good levels of resistance to these diseases. The scientists also looked at the impact of different tillage systems on the damage caused by wilt on lentil, and found that tillage system did not affect the degree of wilt damage. Other experiments investigated the effect of temperature on *Ascochyta* blight in chickpea. At low temperatures (10–15°C), chickpea genotypes were highly susceptible to stem infection and the fungal pathogens became more aggressive.

Another threat to legume crops – *Chickpea chlorotic stunt virus* – was monitored through field surveys in West Asia and North Africa. Researchers found the virus for the first time on legumes



Stripe rust on wheat in Morocco: the recent epidemic occurred when a new disease variant overcame the commonly used resistance gene Yr27

in nine countries: Azerbaijan, Egypt, Eritrea, Ethiopia, Morocco, Sudan, Syria, Tunisia, and Yemen.

Also in 2009, researchers looked at the population dynamics of the fungal disease stripe rust on wheat. The ICARDA team found that the recent pandemic in CWANA could be due to the spread of one particularly virulent rust population, which has overcome the disease resistance usually provided by the wheat gene *Yr27*. ICARDA is therefore carefully monitoring the spread and virulence of the disease using trap nurseries and race analysis of the rust fungus. This, and further breeding for resistance at ICARDA, will help to reduce the impacts of the disease in the region.

Creating a regional seed market

To get the most from their land, farmers in arid countries need

access to good quality seed of disease-resistant crop varieties. This access requires regulation, to ensure that seed stocks are healthy. However, when countries within a region have conflicting regulatory systems, accessing seed across national boundaries can be difficult.

To improve regional access to seed, ICARDA worked jointly with the Economic Cooperation Organization (ECO) and the Food and Agriculture Organization (FAO) between 2006 and 2009 on strengthening the seed trade sector in the ECO region of Central Asia. The project has now achieved its aims of harmonizing regulatory frameworks associated with variety release, seed certification and phytosanitary measures, and establishing the ECO Regional Seed Association (ECOSA). Both achievements have been endorsed by senior government officials of ECO member countries.

The seed project reached its climax with the First ECOSA International Seed Trade Conference (ECOSA 2009) held in December 2009 in Antalya, Turkey. The Turkish Seed Union (Turk-TOB), in partnership with ECO, FAO, the Turkish International Development Agency (TIKA), and ICARDA organized the conference under the auspices of the Turkish Ministry of Agriculture and Rural Affairs.

The ECOSA conference promoted regional seed trade among seed companies within and outside the region, and gave seed industry stakeholders a chance to share experiences. Conference participants came from the private and public sectors, international, regional and national seed trade associations, international organizations working on seeds, and centers of the Consultative Group on International Agricultural Research (CGIAR).

The seed project has produced several key reports. These include country-specific studies on the privatization of the seed sector (Kazakhstan, Kyrgyzstan, Pakistan, and Turkey), regional studies on the diversification and development of industrial crops in Central Asia and the Caucasus, and a synthesis report on the seed sector analyzing opportunities for the future.

Testing seed health

Healthy seed stocks are essential for successful plant experiments and breeding programs. For this reason, ICARDA's Seed Health Laboratory (SHL) makes sure that all seed going to and from ICARDA is free of disease. During 2009, the SHL tested around 40,000 accessions of incoming and



The ECOSA Seed Trade Conference brought together industry representatives, scientists and development experts

outgoing seed. This comprised 301 shipments that were dispatched to 69 countries.

Within the 47 incoming shipments from 23 countries, SHL identified 12 that were infected with quarantine fungi. These shipments were then incinerated. SHL scientists also carried out field inspections and removed and destroyed any diseased plants they found.

As well as working within ICARDA, the Seed Health Laboratory has provided technical advice to research institutes in dryland countries. It advised the Konya Research Institute in Turkey on upgrading seed health and post-harvest facilities, and provided support in Dubai for the creation of a new seed health unit. SHL also contributed to an international training course on genebank operations in Sweden and trained two scientists from Turkey and Cyprus for two weeks.

ICARDA's Seed Health Laboratory has taken a direct role in research

too. In an international collaboration with Montana State University and the French National Institute for Agricultural Research (INRA), SHL has identified which of ICARDA's dryland crops are sources of bacteria capable of acting as biological ice nucleators. When airborne, these bacteria have the ability to create 'ice nuclei' that catalyze the formation of raindrops. But the research team has also been evaluating the possibility that the bacteria may help disseminate the spores of wheat rust diseases.

SHL is also supervising five research theses on the topics of epidemiology, seed transmission and control, and new methodologies to identify seed-borne pests.



Fields are continually monitored for diseased plants, to prevent the spread of diseases



Integrated Water and Land Management

Summary of achievements

Some of the main achievements of the Integrated Water and Land Management Program in 2009 are as follows:

- The first phase of the West Asia and North Africa water benchmarks project ended and the second phase, funded by the Arab Fund for Economic and Social Development, began.
- The two Challenge Program projects on water productivity and ecosystems resilience in Iran ended and a regional project on the productive use of gray water in home-farming began.
- Several indicators of soil fertility were developed to compare conservation agriculture with conventional agriculture, and in Central Asia a phosphogypsum technology was disseminated to overcome problems caused by excess magnesium in water and soils.
- New research trials were established in Tel Hadya on zero tillage and supplemental irrigation of improved wheat genotypes and on the response of food legumes and bread and durum wheat to different levels of water application.
- New projects were launched on land management in Jordan, Lebanon, Palestine, and Syria, on 'unlocking rainfed potential' in Ethiopia, and on climate change in Central Asia.
- Three training courses and workshops on water productivity, transboundary river basin issues, and saline water and soils were held at ICARDA headquarters and a course on crop simulation modeling with CropSyst software was conducted.
- A mega-project was launched in Libya to test integrated water and land management options in benchmark watersheds.

salts and metals. In many fields, especially those close to wastewater channels, salinity levels were found to be higher than the critical limit (4 dS/m) that affects crop yields. Climate change is likely to make the situation worse, as decreasing rainfall will not sufficiently leach contaminants from the soil and intense showers will create runoff that may contaminate neighboring clean soils.

To maximize the safe and productive use of wastewater, therefore, ICARDA-IWMI studies have recommended a suite of actions. These range from optimizing the performance of wastewater treatment plants and separating industrial from domestic wastewater, to encouraging industries to treat their wastewater. The studies also recommended restricting the disposal of untreated wastewater to prevent surface water becoming contaminated, and monitoring the build-up of pollutants in crops, surface water, groundwater and soils in areas where farmers use wastewater to irrigate. These measures need to be complemented by capacity building, enforcing standards on wastewater treatment and reuse, and identifying policies and institutional set-ups that will facilitate wastewater reuse.

Rainwater harvesting greens the steppes

Many of the rangelands in dry areas are degraded. Desertification is now starting to affect the

Optimizing use of wastewater

The rising scarcity and cost of freshwater drive farmers in dry areas to use partially treated, diluted, or untreated wastewater to irrigate their land. But this carries environmental and health risks that are not fully appreciated by most farmers and some government agencies. ICARDA is working with the International Water Management

Institute (IWMI) to address the pros and cons of irrigating with wastewater. Economic analyses showed that around Aleppo, Syria, farmers can double their returns by irrigating with wastewater instead of groundwater.

However, researchers have also observed that long-term use of partially treated or untreated wastewater can damage soil quality and lead to poor crop growth, due to increased levels of



ICARDA research is helping to identify ways to conserve groundwater and prevent over-irrigation with no loss in crop productivity

adjacent fertile lands, resulting in falling yields and degradation of these areas too. As rangeland vegetation becomes scarce, people face greater social and economic pressures, and these often lead to yet more rangeland degradation. People whose livelihoods depend on livestock are often forced to migrate to urban centers. However, research has shown that rangelands can be rehabilitated and desertification can be reversed.

By harvesting the little rain that falls on the steppe, ICARDA researchers have shown that enough water can be provided for indigenous shrubs and grasses to grow, so stopping erosion and degradation and supporting livestock. Rainwater harvesting and appropriate grazing management can change the face of the steppe.

ICARDA has combined modern tools with indigenous water-harvesting knowledge to develop and rehabilitate large areas of dry rangelands. At benchmark sites in Jordan and Syria, the project mechanized the construction of

water harvesting structures, using laser-guided land-leveling and planting techniques to cover large areas quickly and cheaply. One person using a tractor fitted with laser-guided equipment can construct micro-catchments on up to 30 hectares in a single day.

Research over 10 years has shown that some shrubs and grasses not only grow vigorously, providing increased livestock feed, but can also survive years of continuous drought. The system helps increase biodiversity and builds up a better soil seed bank. The economics of the system show positive returns even without considering the environmental benefits.

Now that water-harvesting systems have been shown to be feasible, policies are needed to support investment in the rangelands. As most of the benefits are environmental and social, public funding is needed for communities in these areas. Institutional and land tenure reforms are also essential to promote the wider adoption of water-harvesting techniques.

Micro-credit helps fight land degradation

On steep hillsides, rainfall can be sudden and intense, washing away soil and reducing crop yields. Climate change adds to this problem by increasing the frequency of severe storms. To prevent and cope with land degradation, farmers can create landscape features to conserve soil and water, and can diversify their farming systems. However, these changes mean investing capital, which is beyond the reach of many resource-poor farmers.

To help farmers tackle land degradation, ICARDA is developing a novel approach: community micro-credit systems. A team from the Center helped two communities in hilly olive-growing areas in north-west Syria to obtain grants from the Global Environment Facility's Small Grants Programme (SGP), which is implemented by the United Nations Development Programme.

A community committee, with support from ICARDA staff and the national extension service, distributes the SGP finance to farmers in the area via micro-credit funds. Initial experience showed that building soil and water conservation structures on scattered fields was not the most efficient way to deliver positive impact at the medium scale. Scientists and local people therefore worked together to produce a community watershed plan.

In this plan, the team subdivided the village area into watersheds, each classified according to potential erosion risk. Next the team mapped boundaries of 168 farms within the watersheds and classified each field according to

erosion risk. The community committee then distributed funds to 52 farmers based on the priority need of their farms for soil and water conservation measures.

Early results show that building semi-circular embankments reduced rill erosion by 40% and captured 3.4 tons of sediments per hectare per year. Scientists are now developing computer-based watershed models to assess how well the approach limits the negative impacts of extreme rainfall events at watershed and field levels. The team will then out-scale the approach to other communities in similar environments.

Supplemental irrigation gives crops a head start

In rainfed farming in dry areas, crop yields and thus farmers' incomes are low and vary greatly from year to year, because of variations in both the total amount of rainfall, and its distribution within a cropping season. Supplemental irrigation overcomes these problems by applying a little water only when there is insufficient rain for normal plant growth. Optimally timed irrigation can substantially improve productivity and efficiency, and is especially important in areas where water is scarce and new water resources are limited.

Results from the water benchmark project in Morocco, the CGIAR Challenge Program on Water and Food project in Karkheh, Iran and the highlands program in Turkey have all shown that supplemental irrigation can also extend the growing season, leading to higher yields.

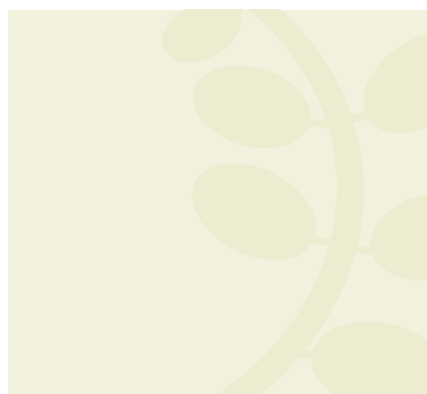
If rains arrive late, the planting of rainfed crops without

supplemental irrigation is delayed. So, by the time the cool season starts, winter crops such as wheat are often under-developed and unable to benefit fully from the frequent rainfall that arrives later in the season. They are also more susceptible to frost. However, as little as 50 mm of supplemental irrigation applied to early-planted crops can overcome this problem, allowing plants to benefit fully from later rains.

In Morocco, 50 mm of supplemental irrigation increased average yields of early planted wheat from 4.6 to 5.8 tons per hectare (t/ha), with a 50% increase in water productivity (the yield produced per unit of water used). In Iran, a single supplemental irrigation increased yields of wheat from 2.4 to 3.8 t/ha and of barley from 2.2 to 3.4 t/ha, with water productivities of about 2.53 kg per

cubic meter. In Turkey, supplemental irrigation increased wheat yields from 3.4 to 5.3 t/ha, with water productivity up to 3.7 kg per cubic meter.

Supplemental irrigation maximizes both yield and water productivity. When water resources are limited, options like supplemental irrigation should be used and policies adopted to create the necessary enabling environment.



Research trials in Iran: a single supplemental irrigation increased wheat and barley yields by more than 50%

More crop per drop with supplemental irrigation

The Karkheh River is the third longest river in Iran, with an annual flow of more than five cubic kilometers. Agriculture is the major activity in the Karkheh River Basin with rainfed production upstream of the newly-built Karkheh Dam and fully irrigated production downstream of the dam. Both systems suffer from low water productivity and the basin has endured water scarcity and frequent droughts, which adversely impact on farmers' livelihoods. So even though 90% of water in the country is used for agriculture, this is not currently enough to ensure food security. Increasing water productivity (amount of 'crop per drop') is the only option.

In order to increase water productivity, and thereby enhance food security, ICARDA teamed up with the Iranian Agricultural Research, Education and Extension Organization (AREEO) on the Karkheh River Basin Project. This project forms part of the CGIAR Challenge Program on Water and Food. Other local partners on the Karkheh River Basin Project in Iran included the Dryland Agricultural Research Institute, the Agricultural Engineering Research Institute, and the University of Tehran, as well as extension agents and farmers from Kermanshah and Lorestan Provinces.

Testing supplemental irrigation on rainfed crops

Looking at the agro-climatic characteristics of the upper Karkheh River Basin, it occurred to scientists from AREEO and ICARDA that water productivity could be substantially increased by optimizing supplemental irrigation. To test this hypothesis, the research team selected two benchmark sites. These sites, the Honam and Merek watersheds, represented the prevailing rainfed crop, rangeland, and forest environments with differing water resources for supplemental irrigation.

The team carried out on-farm trials to assess how supplemental irrigation affected the yields of wheat and barley over three seasons. In both watersheds, just one 75 mm supplemental irrigation given to early crop sowings increased yields of wheat and barley by more than 50%. And giving an additional 75 to 100 mm



Technology packages based on supplemental irrigation are being tested and scaled out across the Karkheh river basin in Iran

of water in the spring more than doubled yields. This had the effect of increasing water productivity by 50 to 100%.

Potential for up-scaling

What is particularly interesting about the ICARDA/AREEO results is that they translate to an area of about 2000 square kilometers in the upper Karkheh basin. This means that there is great potential for up-scaling supplemental irrigation and increasing wheat and barley production for Iranian farming communities in the basin.

Combining technologies to combat climate change

Climate change is likely to increase the severity of drought, water scarcity, and heat stress, and so reduce crop yields. ICARDA has been developing adaptation strategies and packages to enable farmers to cope with the conditions expected.

Researchers used the CropSyst model in Syria to simulate the effects of different scenarios of higher temperatures and lower rainfall on wheat yields. They also looked at how far the effects of supplemental irrigation at critical growth stages can reduce yield losses and increase total production.

Previous work has shown that supplemental irrigation, zero tillage and improved varieties increase wheat yields under drought conditions. However, the effects of combining these three technologies into a single package have not been studied before.

ICARDA therefore studied the interaction of these three factors in field trials in 2008/09.

Researchers showed that zero tillage improved wheat growth and evapotranspiration early in the season for all the improved wheat genotypes tested. Limited amounts of supplemental irrigation during stem elongation and grain filling periods increased the number of grains per spike and seed weight.

The combination of all three technologies increased the total amount of water used by the crop by 110 mm compared with conventional tillage under rainfed conditions. Grain yields increased from 4.52 to 5.93 t/ha, but water productivity (yield per unit of water) was not significantly

affected. All the improved varieties tested responded positively, but differently to the combination of zero tillage and supplemental irrigation; Cham 6, Cham 8, and Shuha were the most responsive.

This study showed that zero tillage reduces evaporation and increases transpiration early in the season, while supplemental irrigation reduces the effects of terminal drought. It also showed that the combination of the three technologies can increase and stabilize yields. The combination can thus be seen as another drought adaptation strategy to help farmers cope with climate change.

New water and livelihoods initiative

The overuse of water, resulting in the degradation of agro-ecosystems, is the single largest concern facing farming families, rural communities, and natural resources all over the Middle East. It is the main threat to economic development, food security, and stability in many parts of the region.

The Middle East Water and Livelihoods Initiative (WLI) is a new program targeting the most vulnerable people and addressing the major constraints to improved food security and livelihoods in the Middle East and North Africa region. ICARDA is the lead partner in the initiative, funded by USAID.

WLI focuses on self-reliance and capacity development in the seven participating countries: Egypt, Iraq, Jordan, Lebanon, Palestine, Syria, and Yemen. It will use the regional expertise and established relationships of ICARDA, the International Food Policy Research Institute, and the International

Water Management Institute, as well as the skills of US universities and the in-country knowledge and human capital of many stakeholders.

The strength of WLI is its emphasis on the use of existing data, social capital, research, partnerships and proven methodologies and technologies in the Middle East. This will ensure that improved livelihoods will be generated from the very beginning of the project.

In the fall of 2009, ICARDA was awarded a start-up grant from USAID to begin implementing regional activities throughout the WLI partner countries. A kick-off meeting was held in February 2010 in Amman, Jordan, where stakeholders came together to discuss and finalize the WLI work plan for 2010. Planned activities for 2010 include characterization of benchmark sites and the launching of needs assessments in the fields of education, knowledge-sharing, extension, and policy.



Innovative irrigation methods using treated wastewater are improving productivity and farm income in water-scarce countries

Water and Livelihoods Initiative in Egypt

Water scarcity is an increasing concern for Egyptian farmers, highlighting the need for better water management practices. Indeed, efficient water management has a direct correlation with improved rural livelihoods. For this reason, Egypt is one of seven countries participating in ICARDA's Water and Livelihoods Initiative (WLI). The initiative, designed in 2009 with stakeholders from across the region and the United States, builds on the work of ICARDA's Water Benchmarks Project for the Central and West Asia and North Africa (CWANA) region. That four-year research project addressed water scarcity and water-management options for farmers in three agro-ecosystems and 10 countries.

In Egypt, the WLI focuses on the Nile Delta, which includes three benchmark sub-sites used in the CWANA Water Benchmarks Project, and reflects the full spectrum of irrigation issues in Egypt. Although the WLI will initially focus on the benchmark sites, scaling up successful techniques to the national level is an important goal of the project.

Identifying priorities

ICARDA worked with Egyptian stakeholders to identify priority activities at a development workshop in Cairo in 2009. The priorities that emerged included better irrigation and soil management, improved cropping systems, and increased access to new technologies. Project participants agreed that building on the existing benchmark sites would be beneficial, as the WLI would be able to tackle problems not yet addressed and introduce innovative methods to serve the local community. These innovations include organizing farmer field schools in collaboration with regional and national universities, and introducing new technical inputs such as GIS modeling using ground-penetrating radar.

Providing training and enabling ownership

Training provided through the WLI will include short-term local and regional courses and long-term academic studies in identified priority areas. Short courses will include programs for national agricultural research and extension systems' staff,



The Water and Livelihoods Initiative will promote practices, such as sprinkler irrigation, that maintain or increase yields with significantly less water

farmers, and community leaders. It will also include train-the-trainer courses to ensure sustainability and enable community leaders to conduct training courses themselves. Long-term training will involve post-graduate education at the master's and doctoral levels in partnership with regional and US universities. This will strengthen human capital in Egypt and in turn will increase the impact of research and development in the region.

To ensure broad participation and create a sense of ownership among stakeholders, the WLI will form site advisory groups, water user associations, and farmer interest groups. These will enable local communities to tailor the initiative to their needs and further participate in the design and implementation of project activities.

Immediate activities in Egypt will include baseline studies at the benchmark sites, as well as an educators' workshop scheduled for June 2010 at the American University in Cairo to solidify all education-related activities throughout participant countries. With broad support from Egyptian agricultural centers, universities, community-based organizations, and advanced research institutions, the WLI is well-positioned to make a lasting impact to improve the livelihoods of rural households.

Diversification and Sustainable Intensification of Production Systems



Summary of achievements

The main achievements of the Diversification and Sustainable Intensification of Production Systems Program in 2009 include:

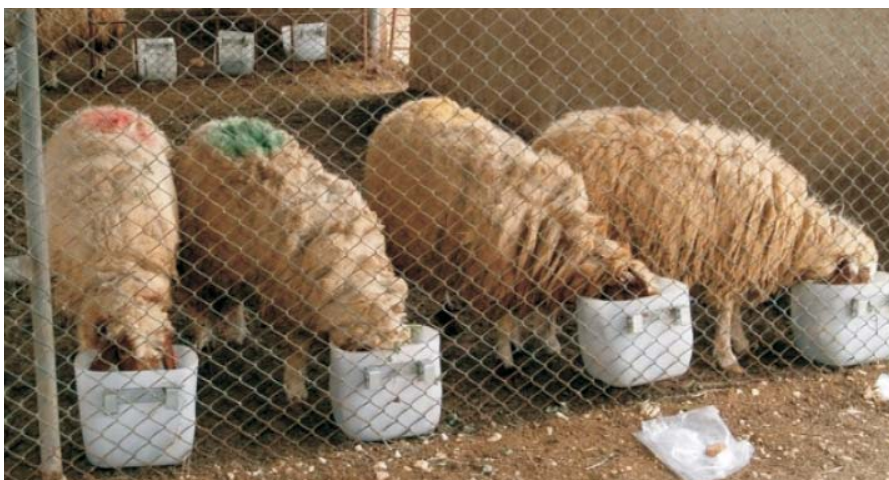
- Collecting rangeland seed and creating field genebanks for pastoral and multi-purpose species with national agricultural research systems (NARS) to display plant materials suitable for dry areas, conserve threatened native species, and identify species for reversing rangeland degradation.
- Introducing the 'digital vegetation charting' technique: a new method for rapidly and objectively monitoring and assessing rangeland condition at the local scale.
- Disseminating best practices for forage and livestock production to more than 300 farming families in an IFAD-funded project.
- Reducing feed costs – without affecting dairy product quality – for small-scale sheep farmers in West Asia, by promoting under-used agro-industrial by-products and crop residues as fodder crops.
- Testing community-based breeding programs with 500 households and four local sheep breeds in Ethiopian small-scale production systems.
- Increasing yields and crop diversity for horticulturists. Farmers have adopted hydroponic systems in more than 150 greenhouses and have received technical assistance on growing and processing date palm in six countries.
- Promoting conservation agriculture and early sowing to farmers in Iraq and Syria to increase yields and save costs.

Monitoring and conserving rangelands

Guided by the Center's new Livestock Research Strategy (2009-2016), ICARDA's Rangeland Ecology and Management Section (REMS) has been working to monitor and improve rangelands across North Africa and West and Central Asia (CWANA). Rangeland grasses and shrubs are vital sources of feed for livestock in arid areas. A healthy rangeland, with good vegetation cover, enhances water infiltration, limits soil erosion, improves meat and dairy yields, and raises the incomes of resource-poor pastoralists.

In order to conserve native plant material and species with a high nutritional value, ICARDA has collected seeds from rangelands across the CWANA region. ICARDA scientists and partners are using these seeds to establish and develop plant nurseries and 'field genebanks', and are testing promising species for nutritional value and palatability to livestock. A series of 'cafeteria' trials at ICARDA's Tel Hadya research station in 2009 looked at seasonal changes in sheep preferences for salt-tolerant shrubs, and their palatability and nutritive value.

REMS has introduced a new method known as the 'digital vegetation charting' technique (DVC) to estimate amounts of vegetation cover as an indicator of rangeland health. The charting technique, which was developed in partnership with Oregon State University, USA, has several advantages over conventional



This 'cafeteria' trial at ICARDA's Tel Hadya station helped identify the most palatable rangeland shrubs for livestock

Saving water with buffel grass

Pastoral communities of the Arabian Peninsula live in a harsh environment where water is scarce and soils are often saline. Large areas of land suffer from some form of desertification, mainly caused by overgrazing by livestock. This situation first came about in the 1960s, when livestock production increased sharply, thanks to better veterinary services and subsidies that enabled farmers to purchase processed feed and baled hay.

Overgrazing reduces the productivity of an ecosystem, as well as the nutritional value and relative abundance of plant species. And when rangelands do not provide sufficient rainfed forage, farmers extract groundwater to produce irrigated forage – further exacerbating water shortages. Unless current practices change, water resources will be rapidly depleted, indigenous species and technical knowledge lost, and the natural resource base destroyed.

Reintroducing indigenous species

ICARDA, through the Arabian Peninsula Regional Program (APRP), aims to redress the natural balance of rangelands by promoting indigenous species that can provide forage for livestock and simultaneously rehabilitate degraded soils.

In close collaboration with the national agricultural research and extension systems (NARES) of the Arabian Peninsula, APRP has introduced indigenous buffel grass (*Cenchrus ciliaris*) as an irrigated forage to replace the exotic Rhodes grass (*Chloris gayana*), which despite its high water requirements is a widely used forage crop on the Arabian Peninsula.

Buffel grass is high-quality forage, which animals find very palatable. And although the annual yield of buffel grass under drip irrigation is equivalent to that of Rhodes grass (20 tons of dry matter per hectare), it uses 50% less water.

Through the ICARDA project, buffel grass has now replaced other forage grasses under drip irrigation on more than 60 farms in the United Arab Emirates. APRP has set up 20 demonstration plots in the other



Buffel grass – a high quality and very palatable fodder – uses 50% less water than the exotic Rhodes grass, which is commonly grown on the Arabian Peninsula

six countries of the Arabian Peninsula to help persuade NARES to follow suit. And to help them obtain high-quality seed, APRP has established seed multiplication fields together with three seed technology units in the United Arab Emirates, Oman, and Saudi Arabia. Four more units are in the pipeline for the other countries in the region.

Sustaining livelihoods and natural resources

Livestock (mainly sheep, goats, and camels) are a major part of the agricultural economy on the Arabian Peninsula and of vital importance in sustaining the livelihoods of rural people. Buffel grass technology will benefit the thousands of farmers in the region who grow forage crops for their livestock.

And there are environmental benefits too. The combination of improved forage production with increased water efficiency reduces pressure on degraded rangelands and makes efficient use of scarce water resources.

The buffel grass technology package is just one of the outputs of APRP's decade-long collaborative research, which has also focused on capacity development and institutional strengthening of NARS. In this work, APRP identified and promoted appropriate technology, provided training to NARS staff and pilot farmers, and helped establish seed-multiplication fields and government seed-technology units to ensure an adequate supply of seed.

methods. In particular, it is a rapid, objective approach that captures details without destroying rangeland vegetation. And the technique is easily repeated, allowing for comparisons over time and space. Scientists in NARS and other ICARDA programs are keen to acquire the DVC software and REMS is now providing training in its use.

Other research has worked directly with pastoral communities. In Central Asia, research financed by the International Fund for Agricultural Development developed farmers' capacity to rehabilitate rangelands. And in Azerbaijan and Syria, a project supported by the OPEC Fund for International Development worked with pastoral communities on using pastures in landscape depressions to alleviate feed deficits. The same approach was adopted on the Arabian Peninsula.

Improving forage cultivation

Farming systems that integrate both crops and livestock are a sustainable way of producing food for dryland communities. Forage crops such as cereals and legumes are an essential element of these mixed systems, whether they are rainfed or irrigated. Throughout 2009, ICARDA scientists collected and tested forage crop germplasm and trialed different forage systems to find out which had the greatest impact on productivity, and therefore food security and income generation. They then worked with farmers to disseminate best-practice results.

To evaluate the protein content and digestibility of different types of triticale (a hybrid of wheat and rye), ICARDA scientists developed a new technique using near

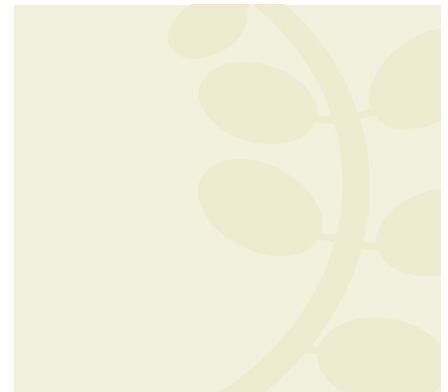
infrared spectroscopy. This is more efficient and cheaper than conventional methods for predicting crude protein, organic matter digestibility, acid detergent fiber, and neutral detergent fiber, and can reduce the cost of evaluating forage germplasm in the future.

Triticale is very well adapted to saline soils. In 2009, researchers assessed the growth of 39 triticale accessions under different salinity levels, and thus identified those with the greatest potential for producing fodder on salt-affected land.

ICARDA teams also looked at the potential of crops to capture and store carbon in their root systems – which is relevant to mitigating climate change. Researchers compared pure stands of cereals (barley, oats and triticale) and forage legumes (common vetch, grass pea and narbon vetch) as well as mixed stands. They found that the below-ground biomass of

triticale was 25% greater than that of oats and barley, demonstrating the greater ability of this hybrid to sequester carbon.

As part of a project funded by the International Fund for Agricultural Development, ICARDA disseminated best practices for forage cultivation to more than 300 poor livestock-keeping families in Syria. These best practices included grazing lambs on oats or barley–vetch mixtures, as these resulted in higher weight gains than grazing on barley alone (the traditional practice).



Training course on animal nutrition: ICARDA scientists work with farm communities to share best practices

Narrowing the feed gap

In low-rainfall areas of Central and West Asia and North Africa, small ruminants (sheep and goats) are a vital source of income for rural people, contributing to livelihoods and national economies through the production of meat, milk, yogurt, pelts, leather, and wool.

The main sources of feed for these ruminants are the natural pastures (rangelands), crop stubble, cereal straw, and barley grain. Livestock move from winter and spring grazing in the rangelands to cultivated areas for grazing of cereal stubble and other crop residues in summer and the fall.

More animals but less feed

Rapid growth in the population of small ruminants in many countries has led to significant changes in the traditional production systems used by farming families. A generation ago, native rangelands provided most of the feed needs of small ruminants. However, the contribution of natural grazing to total feed resources has declined in many countries from around 70% in the 1950s to only 10-25% today. Not only are rangeland resources insufficient to meet current demand, but the absolute level of feed resources is also declining due to overgrazing, loss of vegetation through plowing or harvesting for fuel wood, soil erosion, and land degradation.

Lack of feed means that millions of poor livestock farmers cannot benefit from the growing market for livestock products. Feed scarcity is most severe during the winter and early spring. Farmers in countries such as Syria graze adult and growing sheep and goats on barley pastures during the spring. Other cereals, such as oats and triticale, and/or cereal-legume mixtures have the potential to broaden the resource base for early-spring feed, but these alternatives had not been explored.

Barley is not the only forage

To investigate little-used forage crops, ICARDA carried out a project working with nearly 300 farming families in north-west Syria. In the project, funded by the International Fund for Agricultural Development,



Trials evaluate new forage varieties and new crop combinations that will provide adequate feed supplies in low-rainfall environments

scientists and farmers collaborated to trial forage alternatives to barley in order to reduce the early-spring feed gap.

The trial compared growth rates of weaned lambs grazing pure stands of barley and oats, and barley-common vetch and oat-common vetch pastures. Lambs grazing oat pastures put on an average of 60% more weight each day than those grazing barley pastures (252 versus 158 grams per head per day). Similarly, lambs grazing the oat-vetch mixtures grew 38% times faster than those grazing the barley-vetch pastures.

According to some farmers, lambs grazing oat-based pastures spent more time grazing than those on the barley-based pastures, which could partly explain the higher growth rates. These results suggest that oats could be a viable alternative to barley for early-spring grazing in the non-tropical dry areas of Syria and other countries with similar climatic conditions.

Reducing feed costs for dairy sheep farmers

Sheep kept predominantly for dairy products require feed supplements, in addition to grazing rangelands and stubble fields. In dry areas, a limited supply of feed resources can reduce the productivity of lactating ewes. ICARDA, in collaboration with BOKU University, Vienna, and ETH Zurich, carried out two studies on the effect of using little-known or under-used feed resources on sheep milk yields and the quality of milk, yoghurt, and cheese.

The first study compared a conventional unbalanced diet based on wheat bran and barley grain and straw with five balanced diets containing different proportions of cotton seed cake, molasses, and sugar beet pulp. In two of these diets, the research

teams replaced barley straw with urea-treated wheat straw.

Ewes on the balanced diets produced 18-50% more milk at a lower cost (18-43%) than those on the unbalanced diet commonly used by farmers. The study showed that sugar beet pulp and molasses could replace up to half of the barley grain conventionally used by farmers, and that urea-treated wheat straw could replace barley straw without any negative effect on milk yield and quality.

The second study tested six diets including under-used ingredients such as olive leaves, saltbush (*Atriplex*) foliage, olive cake, tomato pomace (a by-product of tomato processing), sugar beet pulp and molasses, and lentil straw. All diets had similar energy and crude protein contents and were given to stall-fed lactating

ewes. Results showed that diet had no significant effect on milk yield and quality, even though some ingredients were potentially high in anti-nutritive substances, such as phenols and tannins.

Working with farmers in Syria, ICARDA tested on-farm the most promising diets identified in the research station experiments, with positive results. These studies showed that under-used feed resources – agricultural by-products and crop residues – can reduce costs and improve productivity for farmers keeping dairy sheep.



Unconventional low-cost feed resources allow sheep producers to cut costs while increasing milk yields



Sustainable livelihoods for pastoralists

Rangelands are a crucial resource for the poorest people in dry areas. They represent the major source of feed in the livestock production systems of pastoral Bedouins. They are also vital ecological resources with environmental benefits such as cycling nutrients, filtering pollution, and providing medicinal herbs. Today, however, these rangelands are threatened by severe human and livestock population pressure, degradation and eventual desertification.

Empowering the community

In recent years, there has been increased interest in rangeland development and the promotion of participatory approaches involving local communities in the rehabilitation and management of degraded rangelands. A project run by ICARDA and supported by the United Nations Development Programme and the Global Environment Facility is a good example of this holistic approach.

ICARDA's Rangeland Ecology and Management Section and Seed Section, in collaboration with the Badia Improvement Project and the General Commission for Badia Development and Management in Syria, jointly implemented the rangeland project. Local community members were the main players at all stages of the project including planning, implementation, management, and monitoring. But what is really different about the project is that funds were managed by the community, following agreed guidelines and the project work plan.

The ICARDA team worked with a pastoral community in the Badia, the Syrian steppe that covers 55% of the country's land area. The target community lives in an area 50 km north of Aleppo with less than 200 mm of rainfall per year. It consists of 400 households with 37,000 hectares of severely degraded land, 4000 head of sheep and limited alternative livelihood options.

Improving livelihoods

The project's main aim was to improve the range-livestock production system by reducing the feed gap – the scarcity of animal feed in spring – by rehabilitating and managing 100 hectares of severely



Increasing incomes through value addition: small-scale sheep farmers receive training in how to use their new village-based milk processing unit

degraded rangelands, introducing improved Awassi sheep, and strengthening market linkages by establishing a milk-processing unit and a dipping tank to control livestock diseases.

The research team started the rehabilitation program in fall 2007 using indigenous shrub species. A preliminary assessment in spring 2008 was striking. In the grazed area there were only invasive and unpalatable species including *Peganum harmala* and *Noaea mucronata*, but in the rehabilitated area at least nine nutritious native species were found. There was almost 400% more dry matter of forage shrubs in the rehabilitated area than in the grazed area. These results so impressed local people that they decided to double the area allocated to rehabilitation, using their own resources. The improved forage resources together with the introduced Awassi sheep will increase milk and meat production and so improve producers' incomes.

Given the established reputation of the community for its sheep milk products, the milk-processing unit means that, instead of selling milk to a third party and making little profit, producers will be able to improve their milk quality and ask a higher price for their value-added products. This will generate more income to improve the livelihoods of the community.

Improving local sheep breeds

Indigenous breeds of sheep and goats are more adapted to the harsh conditions of dry areas than are exotic breeds imported from temperate areas in Europe, the US or elsewhere. Breeding programs that use indigenous breeds are also more likely to improve adaptation traits fast enough to keep pace with the impacts of climate change.

In order to increase the incomes of small-scale and resource-poor sheep producers in Ethiopia, ICARDA is working jointly with BOKU University in Vienna and the International Livestock Research Institute with the aim of providing access to improved male and female breeding animals. The project, which is funded by the Austrian Development Agency, includes community-based breeding programs, in which farmers themselves decide breeding objectives, strategies, and institutional structures.

The breeding programs have so far focused on four sheep breeds (Horro, Menz, Bonga, and Afar) in eight communities located in four contrasting environments. Nearly 500 households owning about 10,000 sheep are enrolled. The farmers and pastoralists agreed to share the selected breeding rams between flocks – a key deciding factor for the success of the project.

To help the farmers make informed decisions, the research team developed simulation models to identify the expected genetic gains for each breeding option. The scientists also worked with farmers to set up a recording system to monitor the

performance of rams and ewes. The farmers recorded lamb weights at birth, at weaning, and at the ages of 6 months and 1 year, and noted litter size born and weaned.

The project addressed other livestock issues too. The team introduced strategic de-worming of sheep, treatments for various diseases, and improved forage varieties through training and practical demonstrations. It looked at constraints affecting farmers taking sheep or sheep products to market and built the capacity of communities to manage breeding programs effectively.

Getting more from high-value crops

ICARDA's horticultural research during 2009 focused on increasing the productivity of high-value crops. In the seven Arabian Peninsula countries, ICARDA worked with NARS to improve growing systems where soil quality is poor and water is scarce.

In the United Arab Emirates (UAE) and Qatar, ICARDA scientists worked with farmers to test a system of hydroponics (growing without soil). The teams compared the productivity of crops such as cucumber, tomato, sweet pepper, eggplant, and strawberries, under hydroponics and conventional soil systems. In the hydroponics system, water productivity (amount of 'crop per drop') increased more than eight-fold.

As a result of this research, farmers in the Arabian Peninsula have adopted hydroponic systems in more than 150 greenhouses. ICARDA and NARS are providing support to these growers via farmer field schools, site visits, and workshops.

ICARDA teamed up with other NARS to improve methods for cultivating date palm, a tree that tolerates harsh desert conditions. Working in the six Gulf Cooperation Council countries, the team identified the major pests and diseases that can damage



An innovative community-led breeding program in Ethiopia is helping to protect valuable indigenous sheep breeds



Hydroponic systems are well suited to high-value vegetable crops, producing eight times the amount of 'crop per drop' compared to conventional soil-based cultivation

date palms. It also identified some natural enemies that may be useful in providing biological pest control, and determined the most effective (and least environmentally damaging) pesticides.

The scientists tested techniques such as liquid pollination, which proved to be faster, safer and more economical than the traditional method, but just as effective. They also determined the best methods for extracting, drying and storing pollen, and for drying dates.

ICARDA scientists distributed cloned, tissue-culture-derived date palms to farmers, applied a strategy to control red palm weevil, and provided 2 million dirham (US\$0.54 million) to put up 58 small glasshouses for drying dates. They also used lessons learned in the Gulf region to provide technical assistance to farmers in Afghanistan, Ethiopia, Iran, and Libya.

Conservation cropping increases yields

Conservation agriculture is a way of growing crops without plowing or burning stubble, using zero tillage. ICARDA, with support from the Australian Centre for International Agricultural Research and AusAID, has been developing conservation agriculture in Iraq and Syria so that dryland farmers can save time and money, better conserve moisture and soil resources, and sow early for higher yields. The project is implemented through the Iraq Ministry of Agriculture, the University of Mosul, the University of Adelaide, the University of Western Australia, and Agriculture Western Australia.

The ICARDA team carried out trials in Syria using a special zero tillage seeder that sows seed and fertilizer into narrow slits in otherwise undisturbed soil. In these trials, wheat, barley, lentil and chickpea gave consistently

higher yields using zero tillage rather than conventional cultivation, and early rather than late planting. In one trial, barley yielded 3.74 t/ha under the improved zero tillage plus early planting system and 3.35 t/ha under the conventional cultivation plus late planting system commonly used by farmers. This 12% increase in yield, worth about US\$80 per hectare, plus a saving of about US\$20-30 per hectare for each eliminated plowing, demonstrates that zero tillage can make a huge difference economically.

The ICARDA team is advising farmers in northern Iraq on using conservation agriculture to improve rainfed agriculture. It has also collaborated with seeder manufacturers in Iraq and Syria to develop new prototypes of zero tillage seeders appropriate for local farming systems. The seeders cost between US\$1500 and US\$5000, so are affordable and effective. With training from ICARDA, some farmers in Iraq and Syria have modified their own seeders for US\$300-600.

In the 2008/09 season, six Iraqi farmers grew 500 hectares of rainfed wheat using a local seeder modified for zero tillage. Just across the border in Syria, more than 40 farmers used zero tillage on over 2000 hectares. All farmers found that their crops performed better than those of their neighbors.

Social, Economic and Policy Research



Summary of achievements

Some of the major findings of the Social, Economic and Policy Research Program in 2009 are as follows:

- A 2009 study in Turkey showed new wheat varieties more than doubled the yields of older varieties. Adoption of these varieties added about US\$24 million to national income in 2007 alone.
- According to a migration study in Syria, lack of land titles deters people from taking advantage of government land-reclamation programs and formal loans. The study recommended government policies to encourage land titles, which would also encourage the investment in land improvement of remittances from family members working abroad.
- Small ruminant production was shown to be the most favored investment for remittances, and the landless rely mainly on these animals. Matching government funds with remittances invested in small ruminants would thus benefit the poorest directly.
- Pomegranate production in Egypt has dramatically increased over the past 10 years due to higher profitability and expanding demand. A major obstacle to export growth is produce quality, especially in terms of agrochemical residues.
- A poverty assessment study in Sudan found high and widespread income and human poverty, with clear regional differences. Southern Sudan suffered from higher human poverty despite better natural resource endowments.

Measuring the impact of research

The degree to which results from agricultural research are taken up by farming communities is a true measure of success. To quantify the impact of previous research and development, ICARDA carried out two studies monitoring the uptake of new varieties of wheat and chickpea in Turkey and Syria.

In partnership with the Turkish Agricultural Research Directorate and the International Maize and Wheat Improvement Center

(CIMMYT), ICARDA completed a study on the adoption of five new winter and spring wheat varieties (Ceyhan-99, Demir-2000, Karahan-99, Pehlivan, and Saricanak-98). Farmers stated that the new varieties more than doubled their yields (from 1.65 to 3.54 t/ha) under rainfed conditions.

But there were variations between regions. Yields increased by 73% on the plateau, but by only 13% in the lowlands. The new varieties contributed about US\$24 million to national income during 2007; nearly all from rainfed areas.

In Syria, ICARDA has promoted winter chickpea in partnership with the Department of Agricultural Extension and the General Commission for Scientific Agricultural Research and studied its adoption. About 64% of farmers questioned had adopted winter chickpea in the wetter zone (mean annual rainfall of more than 350 mm) and 73% in the drier zone (mean annual rainfall of 250-350 mm). According to the farmers, the most important factors affecting productivity were *Ascochyta* blight (a fungal disease), insect pests, and weeds. Despite this, winter chickpea generally performed better than spring chickpea.

Most Syrian farmers had adopted only one or a few components of the technology package, and only three farmers adopted the full package. More than half adopted the recommended planting date, seed treatment, and disease and weed control. Growing winter chickpea clearly improved productivity, profitability, household income and water productivity, and reduced the labor required.



Studies in Syria and Turkey documented the adoption of new crop varieties and the benefits in terms of income and food security



Studies in dry, poverty-endemic communities in north-west Syria provided new insights into the relationships between migration, technology adoption, and women's control of resources

Analyzing gender roles after migration

Gender roles play an important part in small farm management. ICARDA programs realize they must take account of these roles if they are to effectively boost productivity and incomes for smallholder households. In order to guide its work, ICARDA carried out a study analyzing the impact of migration from rural to urban areas on gender relations within farming households in north-west Syria.

The research focused on Jabal Al-Hos, a rural community where high levels of poverty and arid conditions have forced many to leave their homes and seek work in cities. Recent rural-development activities in the area include land reclamation, planting olive trees and expanding irrigation. The objectives of the ICARDA study were to identify migration patterns, and analyze farmers' investments of remittances and the relationship between rural migration, livelihoods and natural resource management.

The ICARDA team conducted a participatory appraisal in 15 villages and a formal survey of 608 rural households, covering both male and female members.

Analyses show that generally it is not household heads that migrate but rather male household members, sometimes accompanied by female members. A higher male-to-female ratio increases the chances of migration and the poor mainly migrate within Syria. Relatively better-off migrants have the capacity to travel to neighboring countries which offer higher wages, indicating that poverty limits access to migration options.

The team found that agricultural assets such as irrigation systems, sheep, trees, and rehabilitated land are associated with lower levels of migration. Remittances are mainly used for household consumption (75%) but also for investment in land reclamation (de-stoning), land acquisition, tree plantations, and livestock. Women take on a significant share of the work, but their workloads do not



Household surveys are helping to document women's roles in agriculture and identify gender-related factors in technology adoption

necessarily increase as a result of male migration. This is because most male migrants represent 'surplus labor'. Neither do women gain greater control over natural resources following male migration. Because of traditional cultural attitudes, women lack bargaining power. The remaining men in the village tend to take the key decisions.

Adding value to fruit and vegetables

For small-scale horticulturists, adopting new production and processing procedures can add value to fruit and vegetables, and increase farm incomes. With funding from the International Fund for Agricultural Development (IFAD), ICARDA carried out a study of production chains for pomegranates and winter onions in Egypt, and olives and cherries in Morocco, to pinpoint which policies and interventions improve the productivity and income of small farmers.

The ICARDA study focused on Upper Egypt, where nearly all farmers own less than two hectares, and the El Haouz Mountains in Morocco, where about half of all farms are less than one hectare in size. In both areas, poverty is common, infrastructure is poor, and farms are a long way from major markets and export facilities.

Researchers found that most of the Egyptian farmers studied (80%) see agrochemical residues as the major obstacle to export expansion. The study proposed that adopting the FAO's 'Good Agricultural Practices' and improving post-harvest handling would help farmers to access wider markets. And, since Egypt has a very competitive labor

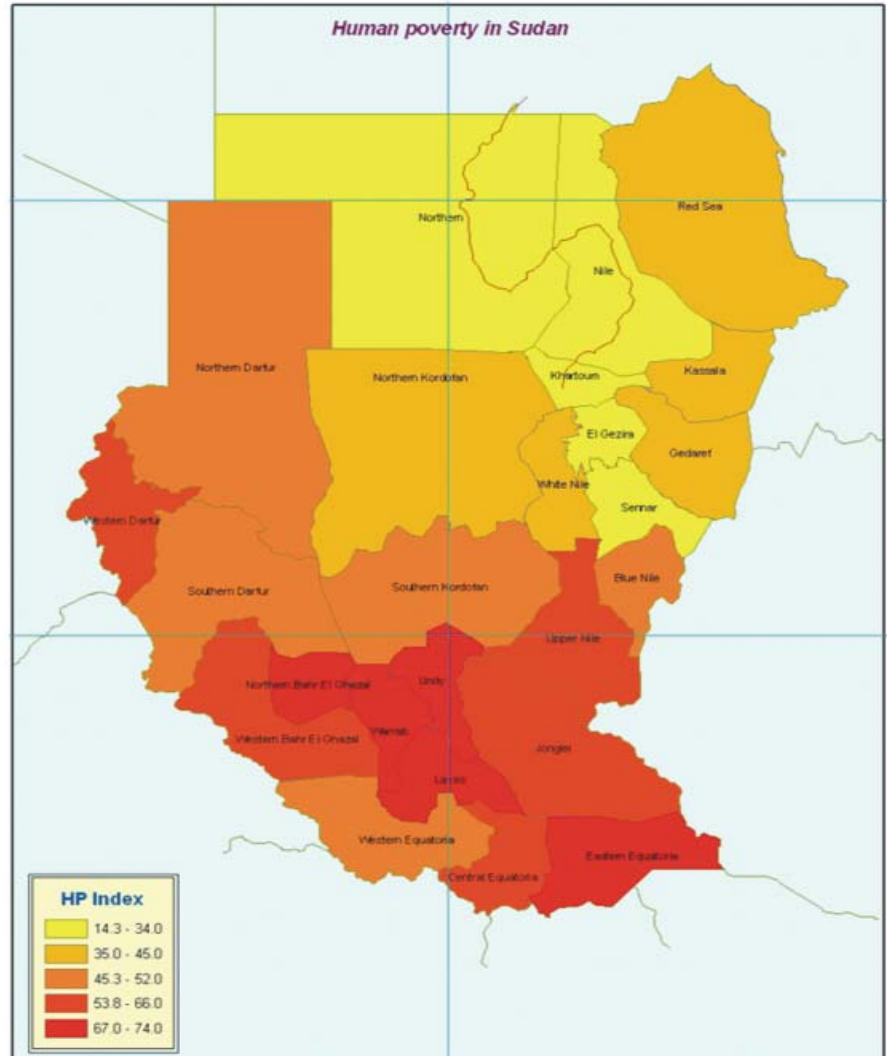
market, more public investment is needed for training farmers in this country to produce high-quality products that fetch high prices.

Morocco is the second largest exporter of table olives after Spain but mostly trades in bulk, failing to capture the added value of retail packaging. This situation is partly perpetuated by the Moroccan government's value-added tax. According to ICARDA, a better government policy would be tax credits for industries that add value to the commodity and increase rural employment. The Center also advised that the dominance of one variety (Picholine marocaine) increases the risk of genetic erosion and disease, so subsidies for this variety should be stopped and diversification promoted.

Assessing poverty in Sudan

Rural poverty is widespread in Sudan. Agriculture employs 80% of the workforce, but most farms are rainfed and susceptible to drought. And, more than two decades of civil unrest have caused extreme socioeconomic inequality. The IFAD Sudan country program aims to work with the Sudanese people to tackle these problems. In 2009, ICARDA contributed to this program by carrying out a detailed poverty assessment and mapping study.

The ICARDA study had three components: household interviews, a literature review, and a computational analysis. The household interviews were conducted in seven Sudanese states to estimate income and poverty levels. The literature review, which included national statistics and recent surveys, charted the evolution of rural poverty in different states. The computational analysis used



This 'poverty map' of Sudan, created using a combination of surveys, GIS analysis and other methods, is helping to identify targets for investment in research and development

existing indices of climate, soil and topography to calculate an agricultural resource potential index (ARI). The ARI provides a means of comparing different states in terms of their potential to support productive agriculture.

The ICARDA analysis showed that poverty is severe and widespread, but with clear regional differences. Southern Sudan, the region most affected by prolonged civil war and underdevelopment, suffers from higher human poverty in spite of relatively better natural resources. However, high levels of poverty persist in both north and south Sudan. Livestock is an important factor in reducing poverty, while

high reliance on field crops is associated with high levels of poverty due to low productivity, particularly in rainfed areas.

The ICARDA researchers concluded that, given constraints on government budgets, development should target those areas that have the highest concentrations of poverty. And, livestock development and technological improvements that reduce large yield gaps should be implemented to increase farm income. The team also pointed out that basic services like healthcare and education are needed to underpin poverty reduction in the long term.

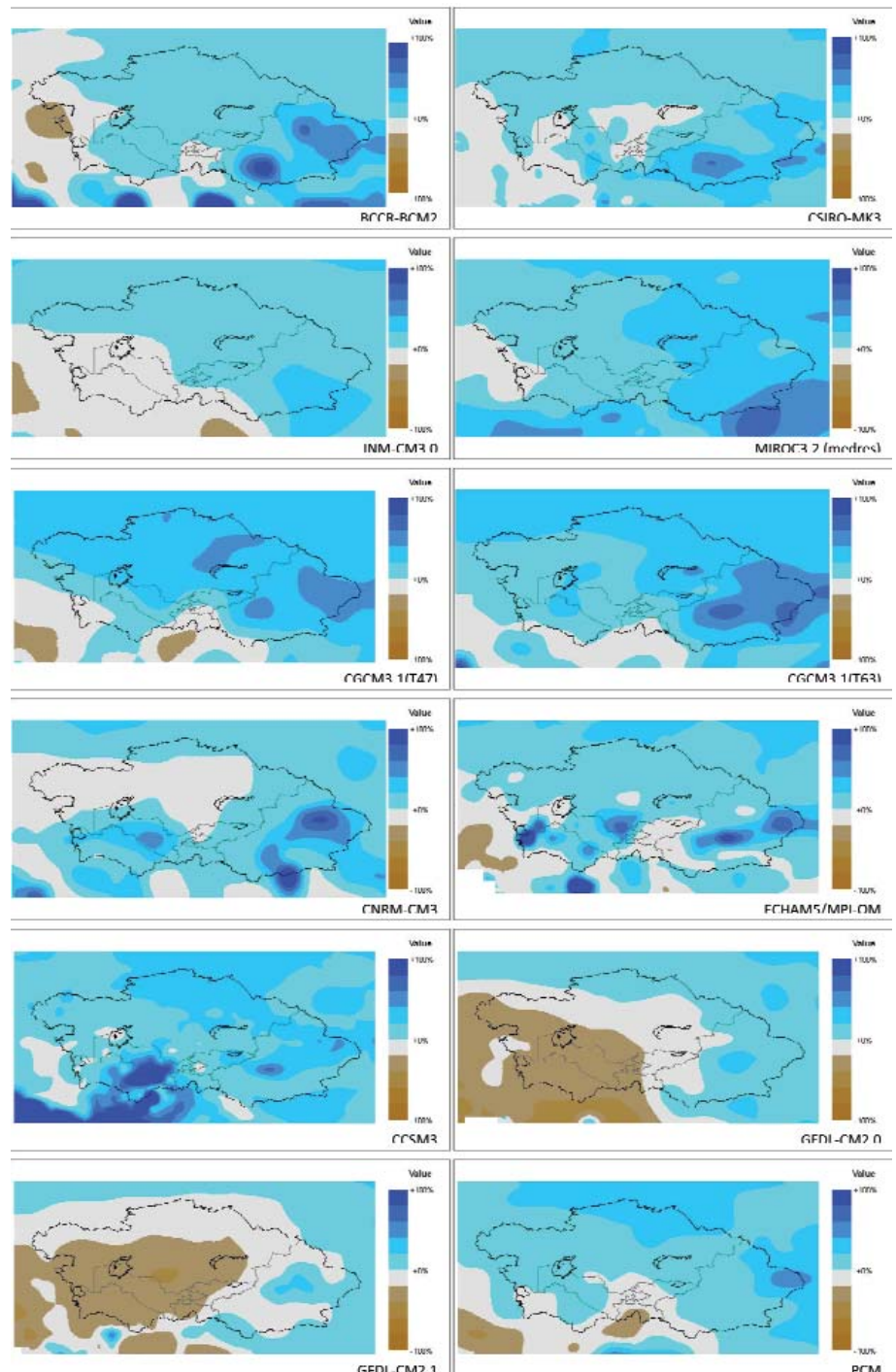
Research Support

Geographic Information Systems

As part of a project funded by the International Fund for Agricultural Development (IFAD), the ICARDA GIS Unit has produced the first high-resolution map of above-ground biomass in Sudan. The Unit developed the map for the project 'Poverty mapping in Sudan' using biome-specific regression models based on the calibration of actual canopy-cover measurements in test sites. These measurements were obtained from Google Earth imagery using the Normalized Difference Vegetation Index (NDVI) derived from Landsat ETM+ satellite imagery.

Using NDVI values derived from MODIS satellite data, the GIS Unit outscaled the regression models for biomass developed from the Landsat images to the whole of Sudan. The results of this study will inform IFAD in establishing natural resource poverty profiles for each state in Sudan, and will also be useful in climate change research.

As part of a project on adaptation to climate change in Central Asia and China, funded by the Asian Development Bank, the GIS Unit developed a spatial database for Central Asia and Xinjiang Province in north-west China. The database consists of more than 5000 high-resolution monthly precipitation and temperature 'surfaces', for three greenhouse gas emission scenarios, three future time horizons and 17 global circulation models. ICARDA will use this huge dataset in 2010 for *ex-ante* impact



Climate change in Central Asia and Xinjiang Province, China: these maps compare rainfall predictions by different models

assessment of climate change in the region.

In order to fill a knowledge gap, the GIS Unit undertook a characterization study on the agricultural environments of Libya using remote sensing, secondary data and field work. The study will be used by scientists of the collaborative research programs between ARC-Libya and ICARDA. It will help them focus research and development interventions in crop, livestock and water management on optimal target areas. It will also serve as the basis of a comprehensive mapping project to identify land suitable for water harvesting in 2010.

As part of a model-based crop monitoring and yield forecasting system in Ethiopia, the GIS Unit developed computer software for mapping climate surfaces using advanced spatial interpolation methods. This software will be used by the FAO in its project 'Support to food security information systems in Ethiopia', and by ICARDA in the next version of the ICARDA Agroclimate Tool (more information on this is available at www.icarda.org/Publications/AgroClimate_Software/AgroClimateTool.htm).

In 2009, the GIS Unit also held several training workshops on remote sensing, agroecological zoning, climate surface generation, soil classification, and map-production techniques for 20 participants from Iraq, Syria, and Cyprus.

Station Operations

ICARDA has two main research stations, established in 1977, for conducting applied research that is transferable to farming



ICARDA is using, as well as promoting, conservation agriculture: 40% of the Tel Hadya farm is now under zero-tillage

communities in similar environments. The main station is at Tel Hadya near Aleppo in north-west Syria with an annex station at Breda, 30 km to the south-east. These stations have mean annual rainfall of 345 mm and 250 mm respectively, and are at 300 meters altitude. A second station is located at Terbol in Lebanon, at a higher altitude (890 meters), with higher annual rainfall (539 mm) and cooler summers; an annex station is located at Kfardane (1080 meters altitude and 461 mm rainfall). Overall supervision is provided by Station Operations.

For winter rainfed crops in Syria, 2009 was a relatively good cropping season, with precipitation falling as light rain rather than showers. However, the rain started quite late in the season and much seeding was done in dry soil. Effective rainfall stopped in late April, coinciding with high temperatures. This was the critical time for cereal grains to fill out, so cereal yields were low for this year. However, lentil was not adversely affected and produced record yields. Grain yields for Tel Hadya crops ranged from 3.4 t/ha for barley and 1.8 t/ha for wheat to 1.3 t/ha for lentil and 1.2 t/ha for chickpea.

ICARDA has increasingly prioritized 'zero tillage' as opposed to conventional tillage. As a result, the amount of zero tillage land at the Tel Hadya research station increased from zero in 2004/05 to almost 300 hectares in 2009/10, or 40% of the total cropland at the station. In general, farmers and researchers gained 20-100% greater yields on zero tillage land than on conventionally tilled land in their own or neighboring fields.

In the very dry season of 2008 (211 mm of precipitation compared with the long-term average of 335 mm), Station Operations did not have the capacity to meet all the irrigation needs of ICARDA research programs. To overcome this problem, a new irrigation unit was purchased. This is fitted with sensors for automatic electronic control, and has pressure-regulated nozzles which allow uniform irrigation rates – both laterally and over time. The new irrigation boom saves energy and water, whilst providing efficient, accurate, and uniform water distribution to ICARDA's research fields.

Capacity Development

During 2009, ICARDA offered training opportunities and internships to 639 national researchers (23% of whom were women) from 41 countries in Asia, Africa, and Europe. Sixteen graduate students completed their thesis research and were awarded MSc and PhD degrees; 48 graduate students will continue their research at ICARDA research stations in 2010.

ICARDA responded to the needs of NARS by offering training on topics identified as gaps in research capacity. ICARDA's Capacity Development facilitated and coordinated training courses covering subjects such as water management; crop improvement; biotechnology; seed production; integrated crop–livestock management; social, economic and policy research; information and communications technology; and best practices for managing research stations.

ICARDA's training program responded to the expansion of the Center's outreach programs in South Asia and China. It thus offered training in biotechnology to scientists from India and Bangladesh, and in socioeconomics to scientists from Mongolia. ICARDA also offered training to scientists from countries with low research and development capacity, such as Eritrea, Mauritania and Palestine, and from areas of conflict such as Iraq, Sudan and Yemen.

New training topics during 2009 included screening for drought tolerance, identifying different pathotypes of wheat stem rust (especially Ug99), developing methods for characterizing small

ruminants, and zero tillage. ICARDA also focused on new advances in technology, such as using molecular markers in breeding plant cultivars that cope with environmental stresses, and combating the impacts of climate change. Topics of high recurring demand included advanced biotechnology and technology transfer.

ICARDA continued its strategy to gradually decentralize training activities through training NARS as trainers. The Center offered train-the-trainer courses on seed production, farm survey techniques, and integrated pest management, and ran farmer field schools in Syria.

To meet increasing demand for training materials, ICARDA has started to develop three electronic training resources on 'Adding value to milk products', 'Economic survey techniques', and 'Best practices for managing station operations'. The Center will publish the digital material on CD-ROMs as well as on the web.

Mobilizing resources for capacity development at ICARDA was a major activity during 2009. The Arab Fund for Economic and Social Development provided substantial financial support and the Japan International Cooperation Agency and the Japan International Research Center for Agricultural Sciences funded courses and graduate students. Many other donors also gave financial support for training as part of their funding of research projects.



More than 600 researchers from 41 countries benefited from ICARDA's training programs in 2009

International Cooperation

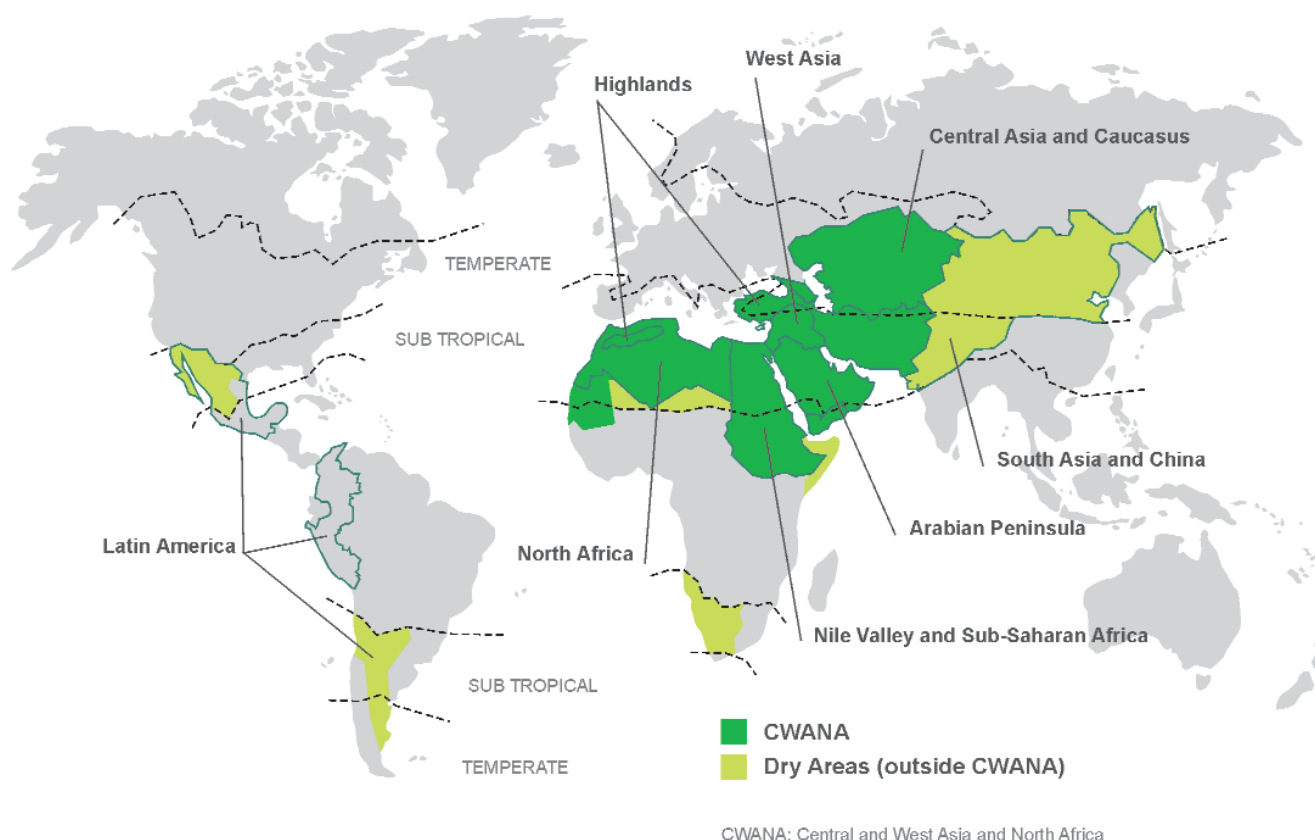
Regional networks ensure that ICARDA's research is appropriate to the needs of farmers and NARS in the places where the new technologies will be used. ICARDA's regional programs, networks and country offices act as a vital two-way link, spreading new technologies to farming communities and feeding back research needs to scientists. And with the looming threat of climate change, ICARDA's research creativity must be perfectly in tune with the economic,

social and environmental conditions in the places where it works, if it is to respond successfully.

ICARDA's regional programs, networks and country offices take a holistic approach to addressing complex challenges, and provide guidance, resources and training to partner NARS and the wider range of stakeholders making up the agricultural community. ICARDA's global reach and NARS' knowledge of national

needs and constraints creates a formidable partnership for delivering technologies to jointly address problems of hunger and poverty. Working together like this is the only way to successfully develop adaptation and mitigation strategies to meet the challenges of climate change, and ensure that food security is within the reach of all.

ICARDA's Regional Programs



Nile Valley and Sub-Saharan Africa Regional Program

The Nile Valley and Sub-Saharan Africa Regional Program (NVSSARP) aims to help increase the incomes of smallholder farmers by improving the productivity and sustainability of agricultural systems while conserving natural resources. It also works in partnership with – and enhances the research capacity of – scientists, research organizations and national institutions in countries throughout the region, including Egypt, Eritrea, Ethiopia, Sudan, and Yemen.

Major challenges

Major challenges facing the region include food insecurity and the degradation of natural resources – particularly water. Many countries in the region lack enabling policies and institutions to support agricultural development; funding and human resources for agricultural research are often inadequate.

Working with communities

In Egypt, ICARDA and national researchers have continued working with communities to improve irrigation management. They are also working on an IFAD-funded project on value chains for medicinal and aromatic plants and horticultural commodities, and on village-based seed enterprises to ensure farmers have access to quality barley and wheat seed.

The regional water benchmark project, supported by the Arab Fund for Economic and Social Development and the OPEC Fund, is developing and introducing improved water management technologies. A partnership between Egyptian, Sudanese and ICARDA scientists has generated

encouraging results in several target environments. NVSSARP is also working with communities to tackle the socioeconomic and policy aspects of water management. In Egypt, these new techniques reduced water and fertilizer application by 25% and 35% respectively, and increased yields by 15%.

The Program continues to collaborate with the Ethiopian Institute of Agricultural Research, ILRI and BOKU (Austria) on community-based livestock breeding and on rainfed agriculture in the Amhara region.

Through the CGIAR Challenge Program on Water and Food, ICARDA has built close working relations with farmer communities and regional agricultural services in Eritrea. It has also contributed to the development of integrated packages to improve food security.

Building partnerships

In 2009, ICARDA and Ethiopia's Federal Ministry of Agriculture and Rural Development signed an agreement to strengthen collaboration. As part of this, an ICARDA-Ethiopia office was officially inaugurated.

ICARDA signed new agreements with Eritrea and the Wheat Improvement Program of the Agricultural Research Center, Egypt.

Taking action

At the 18th NVSSARP Regional Coordination Meeting, the Program and national representatives developed a collaborative work plan for 2010-2012. NVSSARP also played a key role in Arab Water Council coordination and the League of Arab States' Water Ministerial Council planning meetings.



Improved varieties and a lentil-splitting cottage industry boost farmers' incomes

The Program organized three traveling wheat research workshops for national scientists and farmers and arranged numerous training events. In all, over 250 people in the region benefited from ICARDA's capacity-building programs in 2009.

Looking ahead

New projects will link research outputs directly to human development objectives. Efforts to increase incomes and improve the food security and livelihoods of smallholder farmers through increased productivity and resource-use efficiency will continue.

Crop improvement and control of biotic stresses, through an Integrated Pest Management approach, will continue to be important. Abiotic stresses, especially drought and salinity, will be given more attention. ICARDA will capitalize on achievements realized to date, such as improved resource management in Egypt, and extend them to other countries.

North Africa Regional Program

The North Africa Regional Program (NARP) is working to reduce poverty in the region through natural resources conservation, improved crop and livestock productivity, diversification of production systems and incomes, human resources capacity building, and networking. NARP coordinates activities in Algeria, Libya, Mauritania, Morocco and Tunisia.

Water challenges

The challenges facing agriculture in North Africa include a lack of renewable water resources, highly variable rainfall, biotic and abiotic stresses, poor soil fertility, and overgrazing of pastures and rangelands. Additional problems include climate change, high prices of food and feed, and falling public expenditure on agricultural research. Insufficient recruitment of young researchers also hampers efforts to rejuvenate research institutions throughout the region.

Value chains

Examples of project activities include work to improve the value chain for aromatic and medicinal plants in southern Tunisia. Developed under an IFAD-funded project, this has resulted in a 2- to 4-fold increase in marginal profit. A pilot mint production chain was also initiated with the participation of the rural poor, including women. Field days and training sessions were attended by 60 women and 62 men.

Researchers also worked with 50 farmers to implement a no-till system on 803 ha in central Morocco. This new system boosted wheat grain yields by at least 25% – and in some cases over 300% – when compared with the conventional tillage system the farmers were using previously.

Action and agreements

Through the ARC-ICARDA Collaborative Program, NARP has also been fostering ICARDA relations with Libya. Achievements there in 2009 include evaluation of 1500 wheat and barley cultivars under rainfed and irrigated

conditions, collection and evaluation of forage and range species, and the initiation of seed production with farmer participation. The Program has also organized the upgrading of research facilities and training and visits for over 120 Libyan researchers.

ICARDA signed a new agreement with INRA-Morocco in 2009, strengthening the current agreement. The Center also signed a cooperation agreement with the Centre of Biotechnology of Sfax, Tunisia. In 2009, the Program also oversaw the renewal of the INRAA-Algeria-ICARDA Collaborative Program for the period 2010-2014.

Planning

Coordination meetings were held in Libya, Algeria, and Morocco, and a final workshop and steering committee meeting were held in Tunisia for the project 'Water Benchmarks of CWANA'.

Future challenges

NARP will continue its work with countries of the region to address the agricultural challenges it faces. The Program has developed several proposals on food security and is working on a new proposal on climate change in the region.

In 2010 ICARDA, together with nine partners, will start work on a project on conservation agriculture in Africa using funding secured in 2009, for example. A proposal developed by the Program on genetic resources and genebank development in Tunisia will also start in 2010 using funding approved by the Islamic Development Bank, in 2009. The same is true of a proposal on medicinal plants in Morocco, which will be funded by IFAD in 2010.



Better market linkages and new processing methods have transformed mint from a kitchen-garden crop into a major source of income



Women farmers from different countries met in Jordan, providing new perspectives on the criteria used to select new varieties

West Asia Regional Program

ICARDA's West Asia Regional Program (WARP) works to reduce poverty, conserve natural resources, improve crop and livestock productivity, diversify production systems and incomes, and build human resources, capacity, and networking in the region. The Program covers Cyprus, Iraq, Jordan, Lebanon, the Palestinian Authority, Syria, and lowland Turkey.

Food security

The region faces serious food security problems. Major challenges include shortage and scarcity of water, severe and frequent drought, land degradation and desertification, biotic and abiotic stresses, and low investment in agriculture.

Community projects

Examples of the Program's work with communities in the region include the IFAD/AFESD/OFID-funded Badia Benchmark site in Jordan, the ACIAR-funded conservation agriculture project, an IFAD-funded integrated pest management (IPM) project in Iraq, and a Coca Cola-supported project on community-based management of gray water. The gray water

project aims to support the safe and productive use of gray water for crop production. In 2009, this project held meetings with target communities and selected 30 households to test interventions.

Partnerships and initiatives

The Program initiated new partnerships in 2009 with the World Food Programme for Iraq, the FAO-Iraq office in Jordan, and with ACIAR, IWMI and ICBA.

In Jordan, WARP, ICRISAT and the national program are implementing an AusAID-funded project on combating land degradation. In 2009, the project completed a study on changes in land cover in Middle Badia between 1987 and 2006. Also in Jordan, the Program conducted a survey of value chains for medicinal plants, under an IFAD-funded project.

In Iraq, the Program started an IFAD-funded project on IPM and use of organic fertilizer.

Planning and training

Participants from Iraq, Jordan, Lebanon, the Palestinian Authority, and Syria at the 2nd WARP Biennial Coordination Meeting discussed and prioritized future research activities. These included water

management, livestock production, and adaptation to climate change. Participants from Egypt, Iraq, Jordan, Lebanon, the Palestinian Authority, Syria and Yemen, international and regional institutions and universities, and five US universities attended a regional workshop of the Water and Livelihoods Initiative. The meeting developed a strategy and work plan for restoring the Badia rangeland ecosystem and improving livelihoods, identified training needs, and developed a collaborative program between US universities and universities in the West Asia region.

In total, more than 75 trainers, researchers, and students benefited from training opportunities offered by the Program in 2009 on topics including participatory research and extension, biotechnology, soil and water conservation, and disease diagnosis and control.

Future plans

The Program has secured funding from AFESD for a project on community-based seed production in Palestine; activities will start in 2010. The Program will embark on several other new activities and projects in 2010. One project, funded by the Australian Centre for International Agricultural Research, will address salinity problems in Iraq. Other projects in the West Bank and the Gaza Strip, funded by the Netherlands, will be aimed at increasing agricultural productivity and improving the livelihoods of smallholder farmers.

The Program has submitted to IFAD a project proposal on improving food security and livelihoods from rainfed production systems.

Central Asia and Caucasus Regional Program

ICARDA's Central Asia and Caucasus Regional Program (CACRP) works closely with NARS partners on plant genetic resources, crop improvement, soil and water management, feed and livestock production, integrated pest management, socioeconomic and policy research, and human resource development. The Program covers Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan in Central Asia, and Armenia, Azerbaijan, and Georgia in the Caucasus. The regional office is in Tashkent, Uzbekistan.

Research and diversity

The region faces challenges in national investments in agricultural research and young researchers. Policies for the seed sector and for sustainable resource management are pressing problems, as is lack of diversity in production systems, particularly with the imminent threat of climate change.

Workshops and courses

More than 300 farmers, researchers, breeders, seed producers, and journalists participated in field days, workshops, and training courses organized by the Program and its NARS partners in 2009. Participants learned about technologies for sustainable land management, crop improvement, and crop and livestock production developed by the Program and its partners.

The Central Asia and the Caucasus Association of Agricultural Research Institutions, supported by ICARDA, conducted three workshops during 2009 for a total of 90 participants, including



A field day in Uzbekistan organized by the Kashkadarya Research Institute and ICARDA

farmers, representatives of farmer associations and NGOs, policymakers, scientists, and donors.

New initiatives

New initiatives begun in 2009 included a project, funded by the Asian Development Bank, on mitigating the impact of climate change on rural livelihoods in Central Asia, launched by ICARDA with NARS partners and IFPRI, and collaborative research with Kashkadarya Scientific Research Institute for Breeding and Seed Production of Cereal Crops in Uzbekistan.

Through the IFAD-funded project 'Community Action in Integrated and Market-Oriented Feed-Livestock Production in Central and South Asia', the Program forged strong relationships with research institutes in Kazakhstan, Kyrgyzstan, and Tajikistan.

Strategy planning

In 2009, NARS heads and wheat experts from ICARDA, the CAC countries, and the International Winter Wheat Improvement Program, participating in strategy meetings in Tashkent, developed several CAC-focused wheat improvement initiatives. The research priorities include improving yields, end-use quality,

resistance to rusts and Sunn pest, and tolerance to drought, heat, and salinity. The Program also contributed to the second UNECE Environmental Performance Report on Uzbekistan.

Seven Masters and PhD students participated in the ICARDA livestock project in the region in 2009 and collected data for these.

Looking ahead

New initiatives to be launched in 2010 include a three-year project on the utilization of wild relatives in breeding wheat for salinity tolerance and improved quality, funded by GTZ/BMZ; a two-year project on conservation agriculture, funded by FAO; and a two-year project on integrated management of Sunn pest in Uzbekistan, with Tashkent State Agrarian University, funded by FAO.

The Program and its partners have several project proposals under consideration by various donors. These proposals cover mountain agriculture, strengthening capacity in biotechnology, improving wheat grain quality, technologies to conserve resources, crop diversification, and conservation agriculture.

Arabian Peninsula Regional Program

ICARDA's Arabian Peninsula Regional Program (APRP) organizes and coordinates research and strengthens capacity to conserve the scarce water resources and fragile rangelands of the Arabian Peninsula. APRP represents ICARDA in Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates (UAE), and Yemen.

Tackling aridity

Agriculture on the Arabian Peninsula is constrained by high temperatures, extreme aridity, water scarcity, soil and water salinity, and land degradation. Most agriculture is irrigated; the primary crops are exotic fodders and date palm. Overexploitation and inefficient use of water is widespread. The national agricultural research and extension services (NARES) lack trained personnel. National policies promote the import of agricultural commodities so the biggest challenge is to develop appropriate agricultural technologies to improve national food security.

Technology transfer

The Program has developed and transferred to farmers technology packages for protected agriculture and production of irrigated forages. This is having a positive impact in the region. For example, more than 60 growers in the United Arab Emirates (UAE) and more than 20 farmers elsewhere in the region are now growing buffel grass (*Cenchrus ciliaris*) instead of Rhodes grass. Native to the Arabian Peninsula, buffel produces good-quality forage using considerably less water than the exotic Rhodes grass.

More than 100 growers across the region are now using simplified hydroponics techniques and integrated production and protection management (IPPM) systems developed by APRP. The hydroponics system has reduced water use by up to 90% and, compared with conventional soil-based systems, provides higher profits for the growers.

Building partnerships

The Program participated in numerous meetings, symposia, and forums throughout the region in 2009 to promote collaboration among NARES and with ICARDA. The Program also represented the region and ICARDA at international conferences in Canada, India, Syria, and Taiwan. APRP established collaboration with the World Vegetable Center (AVRDC), to develop new technologies for farmers in the Arabian Peninsula.

Planning and training

Forty-five scientists from the seven countries of the Arabian Peninsula, together with ICARDA scientists, attended the 2nd APRP annual planning meeting in Dubai,

UAE. The participants presented collaborative activities in each country and developed action plans for 2010.

Thirteen extension agents from the Arabian Peninsula countries received training in agricultural extension and technology transfer in a course organized by APRP and the Center for Rural Development Researches and Studies, Cairo University, Egypt. The Program also organized several other training workshops, on-the-job training, and farmer field schools for researchers, extension agents, and growers from the region.

Seeking opportunities

The Program is actively seeking new donors and project opportunities. In Kuwait, APRP and the Public Authority for Agricultural Affairs and Fish Resources are developing projects on rangeland rehabilitation and establishment of a genebank. In Qatar, a very ambitious national program for food security is under development with the involvement of ICARDA and other international institutions.



As a result of NARS-ICARDA research, farmers in the Arabian Peninsula have installed hydroponic systems in more than 150 greenhouses

Highland Regional Network

ICARDA's Highland Regional Network contributes to improving rural welfare in the harsh highlands of Afghanistan, Iran, Pakistan, and Turkey. The highlands in all four countries are cold and dry and face similar agricultural challenges.

Afghanistan

Afghanistan imports up to a million tons of food each year. Deteriorating human and physical resources, lack of modern technologies, cultivation of low-yielding varieties, shortages of seed of improved varieties, serious security threats, and insurgency are the major hurdles on the road

to food and nutritional security, and improved livelihoods.

Working with farmers

ICARDA scientists, together with Afghan researchers, farming communities, and other partners, evaluated improved varieties of wheat, chickpeas, lentils, mung beans, potatoes, and rice. The team identified 13 high-yielding wheat varieties resistant to rust (Ug99 and yellow rust). ICARDA established village-based seed enterprises in three provinces that produced over 80 tons of improved mung bean seed. Participatory demonstrations attended by 150 farmers increased awareness of the new varieties. Demonstration plots were used to train more than 300 progressive farmers and VBSE members in best practices for

mung bean cultivation and seed production.

New varieties

ICARDA worked closely with other CGIAR centers and with the World Vegetable Center (AVRDC). As a result, two mung bean varieties (Maash-2008 and Mai-2009) were released by the national program, and improved varieties of potato and rice were identified.

Collaborative research

ICARDA is planning collaborative research for Afghanistan on supplementary irrigation, water harvesting, yellow rust and stem rust, and food and forage legumes. It has trained more than 500 researchers, extension workers, faculty members and students, staff of other stakeholders, and farmers through in-country courses and farmers' field days, while 11 Afghan researchers were trained at ICARDA headquarters and elsewhere.

Looking ahead

Continued collaboration to increase food production and availability, and increase income opportunities in rural communities is imperative. More efforts are needed to introduce improved food and forage crops, increase water productivity and harvesting, disseminate knowledge on crop-livestock intensification and diversification, introduce alternative livelihoods, and provide opportunities for capacity development.



A women's cooperative in Kunduz province, established with ICARDA support, processes mint for sale in local markets



Scientists in Iran select winter-hardy materials from ICARDA nurseries for winter or early-spring planting

Iran

Participatory plant breeding

The Agricultural Research, Education and Extension Organization (AREEO) and ICARDA continued their collaboration on participatory plant breeding of wheat and barley with farmers in Kermanshah Province and expanded it to Semnan Province. Farmers identified 10 superior barley and wheat genotypes in 2009. A survey jointly conducted with the national program found little spread of the rust disease Ug99.

Coordination meeting

The heads of 12 national research institutes, and high-level officials and extension officers from the Ministry of Jihad-e Agriculture and AREEO participated in the 17th Iran-ICARDA Annual Coordination Meeting in September 2009 to review research priorities and develop collaborative programs for 2010 to 2011. The International Winter Wheat Improvement Program, initiated by ICARDA, CIMMYT, and Turkey, strengthened collaboration between Iran and Turkey.

Ug99 and new releases

AREEO and ICARDA strengthened collaboration on monitoring Ug99 and developing varieties resistant to the disease; several promising lines were identified. In 2009, the Dryland Agriculture Research Institute released a new lentil cultivar, Kemia, and a forage vetch, Maragheh, from germplasm provided by ICARDA. The NARS are considering for release several high-yielding lines of bread and durum wheat, barley, food legumes, and forages. More than 40 Iranian scientists and technical staff participated in workshops, meetings, and training courses at ICARDA.

AREEO and ICARDA

AREEO and ICARDA will further strengthen their collaboration on developing improved winter wheat, winter barley, and food legumes, increasing water productivity, managing soils and watersheds, monitoring drought, advancing biotechnology, and improving seed certification and health. They will also strengthen collaborative studies on rust monitoring and developing rust-tolerant wheat varieties, and on conservation

agriculture. The new IFAD-funded regional project on improving the livelihoods of farmers, particularly rural women involved in wool and cashmere production, will start in Kerman province in 2010.

Pakistan

During 2009, research for development continued in Pakistan in close collaboration with national and provincial institutions. ICARDA carried out most of its work in partnership with community organizations for both men and women. Research centered on watershed management, crop improvement (particularly wheat, barley, lentil, and chickpea), livestock feed and dairy goat management for women's livelihoods, and accelerated multiplication of seed. Working with the community, particularly women, has been a great challenge.

Water conservation

During the year, communities themselves built 45 soil and water conservation structures and a bioremediation pond for animal drinking water and small-scale irrigation. Farmers participated in field-scale water productivity and crop diversification trials. Using improved varieties, farmers produced over 3.7 tons of seed of a number of important crops.

Seed multiplication

ICARDA worked together with private companies to produce seed in the accelerated seed multiplication project. This initiative also convinced government institutions to involve private companies in seed production at the very early stages of approval. ICARDA has also started to screen promising wheat lines against local stem rust in hotspot areas of Pakistan.



The ICARDA-led dairy goat project in Pakistan has been remarkably successful in working with farmers – primarily women – to improve milk production and milk products

Building capacity

Five senior managers from Pakistan visited Turkey (with ICARDA support) to familiarize themselves with improved watershed management methods. Similarly, ICARDA arranged a visit to an improved watershed in Pakistan for middle-level scientists. The Center also trained 25 farmers in fodder production, 10 farmers in hay making, and six women and three men in the preparation of cottage cheese.

Looking ahead

Food security is a major concern in Pakistan. Dryland agriculture is the key to achieving food security and ICARDA is making efforts to increase wheat and pulse production.

Turkey

Winter wheat

The International Winter Wheat Improvement Program (IWWIP) works in close partnership with 12 Turkish agricultural research

institutes and CIMMYT. So far, farmers in 12 countries have received 42 cultivars originating from IWWIP. In 2009, these countries included Spain, Tajikistan, and Turkey.

Farmers now grow IWWIP cultivars on around 1.4 million hectares. In 2009, IWWIP provided materials to 90 breeding programs in 48 countries. At a workshop in Turkey, the Program presented to stakeholders the results of a study on the impact of new wheat cultivars in Turkey.

Partnering with Iran

The IWWIP has developed a program of collaboration with Iran to extend activities to new environments represented in that country.

Workshops and training

In order to improve communication of research results, the Network arranged an English course for 75 Turkish national program staff during 2009. A further 39 Turkish

scientists took part in international conferences, workshops, training courses, and short visits; 16 of these visited ICARDA HQ or attended workshops or training programs there.

More than 30 scientists from various countries visited IWWIP activities and made selections from the material in Turkey. Sixty scientists from 19 countries participated in a traveling seminar organized by IWWIP in Ukraine. The Network also conducted a traveling workshop in Turkey on winter wheat and chickpea; participants discussed production constraints with farmers and disseminated new cultivars.

Future projects

IWWIP will focus future efforts on the decentralization of breeding activities in Central Asia and the Caucasus. The Program will expand testing of material for resistance to Ug99 in Turkey and the region. ICARDA and the Southeastern Anatolia Project Regional Development Administration will sign a new Memorandum of Understanding, extending their collaboration.



New wheat varieties, developed jointly with national research centers, are creating significant impacts on food security and farm incomes

South Asia and China Regional Program

The first regional meeting of the South Asia and China Regional Program (SACRP) was held in New Delhi in December 2009.

Participants from Afghanistan, Bangladesh, Bhutan, China, India, Nepal, and Pakistan discussed the improvement of wheat, barley, and food legumes, and natural resource management, all to be combined with socioeconomic research. NARS and ICARDA scientists jointly identified research priorities and are developing projects.

Towards self-sufficiency

South Asian NARS and ICARDA are working toward self-sufficiency in food legumes. Current research covers lentil, kabuli chickpea and grass pea, and will soon include faba bean. Crosses are made for regional short-season environments and the segregating populations are tested and selected locally. ICARDA provides superior plant traits and new sources of resistance to major diseases and abiotic stresses, while ICARDA scientists cooperate in the selection of materials, publications, planning, developing production technologies, and capacity development of young NARS scientists.

Working with communities

The Bangladesh Agricultural Research Institute promoted newly released lentil varieties at field days, during which 200 farmers were trained on improved production technologies, disease and pest management, and post-harvest processing. The Nepal Agricultural Research Council conducted similar activities at Rampur and Nepalgunj, Nepal.

Two barley varieties, developed through NARS-ICARDA



Lentil variety Barimasur 5, developed from ICARDA material, is widely popular in Bangladesh

partnerships, were released in India. PL 807, a feed variety from an ICARDA-CIMMYT cross, is highly resistant to lodging and several diseases, and is intended for irrigated areas in Punjab. It has an average yield of 4.3 t/ha, and seed is being multiplied. Pusa Losar is a dual-purpose variety selected in Shimla from ICARDA material. It is resistant to multiple diseases, producing 15-46% more grain and 6-11% more fodder than standard varieties.

The Nepal Agricultural Research Council released two lentil varieties – Maheshwar Bharathi and Sagun – which are both introductions of ICARDA germplasm with 15-25% higher yields and larger seeds than current varieties. The new varieties are adapted to both the mid-hills and plains regions and are resistant to *Fusarium* wilt, rust, and *Stemphylium* blight. Seed multiplication and distribution have begun.

Centre of Excellence

In 2009, the Chinese Academy of Agricultural Sciences, ICARDA, and ICRISAT jointly established the Center of Excellence for Dryland Agriculture to develop technologies to enhance adaptation, mitigation, and production system resilience under climate change.

Research and training

Numerous ICARDA scientists worked with NARS to develop a regional research agenda at an international conference in Kanpur, India, in 2009.

Twelve Indian scientists attended a training course at ICARDA headquarters on molecular markers for plant breeding. A socioeconomic specialist was trained on impact assessment methodologies and a Bangladeshi scientist on lentil breeding.

Looking ahead

NARS and ICARDA are developing program plans that build on complementary strengths and experiences, especially those of China and India. The recently established Center of Excellence for Dryland Agriculture will expand the scope of its activities, contributing to the global knowledge base, particularly climate change adaptation and related dryland issues.

Legume improvement will continue to be important, as will biofortification research in collaboration with CGIAR Centers and NARS organizations in Bangladesh, India, and Nepal.

Appendices

Appendix 1: Journal Articles

- Abang, M.M., Kabbabeh, S., Ahmed, S., Murad, S., Chilvers, M.I., Peever, T.L. and Schroers, H.J. 2009.** First report of chickpea wilt caused by *Clonostachys rhizophaga* in Syria. *Plant Disease* 93(6): 666.
- Abdel Monem, M., Lindsay, W.L., Sommer, R. and Ryan, J. 2009.** Loss of nitrogen from urea applied to rainfed wheat in varying rainfall zones in northern Syria. *Nutrient Cycling in Agroecosystems* DOI: 10.1007/s10705-009-9297-0.
- Abdelwahd, R., Hakam, N., Labhilili, M. and Udupa, S.M. 2009.** Genotypic characterization of indigenous *Sinorhizobium meliloti* and *Rhizobium sulae* by rep-PCR, RAPD and ARDRA analysis. *African Journal of Biotechnology* 8(6): 979-985.
- Ahari, D.S., Kashi, A.K., Hassandokht, M.R., Amri, A. and Alizadeh, K. 2009.** Assessment of drought tolerance in Iranian fenugreek landraces. *Journal of Food, Agriculture & Environment* 7(3&4): 414-419.
- Al Khalaf, M., Kumari, S.G., Haj Kasem, A., Makkouk, K.M. and Al-Chaab, S. 2009.** Differentiation between susceptible and resistant faba bean, lentil and pea genotypes to *Bean yellow mosaic virus* on the basis of virus movement and multiplication. *Arab Journal of Plant Protection* 27(1): 165-173. (Ar).
- Al Khalaf, M., Kumari, S.G., Haj Kasem, A., Makkouk, K.M. and Al-Chaab, S. 2009.** Use of the two faces of nitrocellulose membrane in tissue blot immunoassay for the detection of *Bean yellow mosaic virus* and the possibility of its mechanically transmitted from the printed membrane to the host plant. *Arab Journal of Plant Protection* 27(1): 91-94. (Ar).
- Ali, L., El-Bouhssini, M., Al-Salti, M.N., Valkoun, J., Nachit, M.M., Abdalla, O. and Singh, M. 2009.** Evaluation of some wheat and its wild relative accessions for resistance to Sunn pest (*Eurygaster integriceps* Put.). *Arab Journal of Plant Protection* 27(1): 73-78. (Ar).
- Asaad, S. and Abang, M.M. 2009.** Seed-borne pathogens detected in consignments of cereal seeds received by ICARDA, Syria. *International Journal of Pest Management* 55(1): 69-77.
- Asaad, N.A., Kumari, S.G., Haj Kasem, A., Al-Chaab, S. and Malhotra, R.S. 2009.** *Beet western yellows virus* (BWYV) in Syria. *Arab Journal of Plant Protection* 27(1): 188-198. (Ar).
- Asaad, N.Y., Kumari, S.G., Haj Kasem, A., Shalaby, A., Al-Chaab, S. and Malhotra, R.S. 2009.** Detection and characterization of *Chickpea chlorotic stunt virus* in Syria. *Journal of Phytopathology* 157(11-12): 756-761.
- Babayeva, S., Akparov, Z., Abbasov, M., Mammadov, A., Zaifzadeh, M. and Street, K. 2009.** Diversity analysis of Central Asia and Caucasian lentil (*Lens culinaris* Medik.) germplasm using SSR fingerprinting. *Genetic Resources and Crop Evolution* 56(3): 293-298.
- Backes, G., Orabi, J., Wolday, A., Yahyaoui, A. and Jahoor, A. 2009.** High genetic diversity revealed in barley (*Hordeum vulgare*) collected from small-scale farmer's fields in Eritrea. *Genetic Resources and Crop Evolution* 56(1): 85-97.
- Bandowe, B., Rückamp, D., Bragança, M., Laabs, V., Amelung, W., Martius, C. and Wilcke, W. 2009.** Naphthalene production by termite-associated microorganisms: evidence from a microcosm experiment. *Soil Biology & Biochemistry* 41(3): 630-639.
- Begdullaeva, T., Orel, M., Rudenko, I., Ibragimov, N., Lamers, J.P.A., Toderich, K., Khalikulov, Z. and Martius, C. 2009.** Productivity of sugar sorghum varieties imported from India under the conditions of Karakalpakstan. [Vestnik] 215: 20-22. (Uz).
- Bhullar, N.K., Street, K., Mackay, M., Yahiaoui, N. and Keller, B. 2009.** Unlocking wheat genetic resources for the molecular identification of previously undescribed functional alleles at the Pm3 resistance locus. *Proceedings of the National Academy of Sciences of the USA* 106(23): 9519-9524.
- Ceccarelli, S. 2009.** Evolution, plant breeding and biodiversity. *Journal of Agriculture and Environment for International Development* 103(1/2): 131-145.
- Chen, M.S., Liu, X.M., Wang, H. and El-Bouhssini, M. 2009.** Hessian fly (Diptera: Cecidomyiidae) interactions with barley, rice, and wheat seedlings. *Journal of Economic Entomology* 102(4): 1663-1672.
- Comadran, J., Thomas, W.T.B., van Eeuwijk, F.A., Ceccarelli, S., Grando, S., Stanca, A.M., Pecchioni, N., Akar, T., Al-Yassin, A., Benbelkacem, A., Ouabbou, H., Bort, J., Romagosa, I., Hackett, C.A. and Russell, J.R. 2009.** Patterns of genetic diversity and linkage disequilibrium in a highly structured *Hordeum vulgare* association mapping population for the Mediterranean basin. *Theoretical and Applied Genetics* 119(1): 175-187.

- Dadi, H., Tibbo, M., Takahashi, Y., Nomura, K., Hanada, H. and Amano, T. 2009.** Variation in mitochondrial DNA and maternal genetic ancestry of Ethiopian cattle populations. *Animal Genetics* 40(4): 556-559.
- Datta, S., Kaashyap, M. and Kumar, S. 2009.** Amplification of chickpea-specific SSR primers in *Cajanus* species and their validity in diversity analysis. *Plant Breeding* DOI 10.1111/J1439-0523.2009.01678.x.
- Djemali, M., Bedhiaf-Romdhani, S., Iniguez, L. and Inounou, I. 2009.** Saving threatened native breeds by autonomous production, involvement of farmers' organization, research and policy makers: The case of the Sicilo-Sarde breed in Tunisia, North Africa. *Livestock Science* 120(3): 213-217.
- Djumaeva, D., Djanibekov, N., Vlek, P.L.G., Martius, C. and Lamers, J.P.A. 2009.** Options for optimizing dairy feed rations with foliage of trees grown in the irrigated drylands of Central Asia. *Research Journal of Agriculture and Biological Sciences* 5(5): 698-708.
- Duveiller, E. and Sharma, R.C. 2009.** Genetic improvement and crop management strategies to minimize yield losses in warm non-traditional wheat growing areas due to spot blotch pathogen *Cochliobolus sativus*. *Journal of Phytopathology* 157(9): 512-534.
- Edea, Z., Haile, A., Tibbo, M., Sharma, A.K., Assefa, D., Sölkner, J. and Wurzinger, M. 2009.** Morphological characterization of Bonga and Horro indigenous sheep breeds of smallholders conditions in Ethiopia. *Ethiopian Journal of Animal Production* 9(1): 117-133.
- El-Bouhssini, M., Chen, M., Lhaloui, S., Zharmukhamedova, G. and Rihawi, F. 2009.** Virulence of Hessian fly (Diptera: Cecidomyiidae) in the Fertile Crescent. *Journal of Applied Entomology* 133(5): 381-385.
- El-Bouhssini, M., Street, K., Joubi, A., Ibrahim, Z. and Rihawi, F. 2009.** Sources of wheat resistance to Sunn pest, *Eurygaster integriceps* Puton, in Syria. *Genetic Resources and Crop Evolution* 56(8): 1065-1069.
- Emebiri, L., Michael, P., Moody, D.B., Ogbonnaya, F.C. and Black, C. 2009.** Pyramiding QTLs to improve malting quality in barley: gains in phenotype and genetic diversity. *Molecular Breeding* 23(2): 219-228.
- Ennahli, S., El-Bouhssini, M., Grando, S., Anathakrishnan, R., Niide, T., Starkus, L. and Smith, M.C. 2009.** Comparison of categories of resistance in wheat and barley genotypes against biotype 2 of the Russian wheat aphid, *Diuraphis noxia* (Kurdjumov). *Arthropod-Plant Interactions* 3(1): 45-53.
- Etela, I., Larbi, A., Bamikol, M.A., Ikhatua, U.J. and Oji, U.I. 2009.** Supplementing Guinea grass with fresh sweet potato foliage for milk production by Bunaji and N'Dama cows in early lactation. *Livestock Science* 120(1-2): 87-95.
- Farahani, H., Izzi, G. and Oweis, T. 2009.** Parameterization and evaluation of the AquaCrop model for full and deficit irrigated cotton. *Agronomy Journal* 101(3): 469-476.
- Fatondji, D., Martius, C., Zougmore, R., Vlek, P.L.G., Bielders, C.L. and Koala, S. 2009.** Decomposition of organic amendment and nutrient release under the zai technique in the Sahel. *Nutrient Cycling in Agroecosystems* 85(3): 225-239.
- Forkutsa, I., Sommer, R., Shirokova, Y., Lamers, J.P.A., Kienzler, K., Tischbein, B., Martius, C. and Vlek, P.L.G. 2009.** Modeling irrigated cotton with shallow groundwater in the Aral Sea Basin of Uzbekistan: I. Water dynamics. *Irrigation Science* 27(4): 331-346.
- Forkutsa, I., Sommer, R., Shirokova, Y., Lamers, J.P.A., Kienzler, K., Tischbein, B., Martius, C. and Vlek, P.L.G. 2009.** Modeling irrigated cotton with shallow groundwater in the Aral Sea Basin of Uzbekistan: II. Soil salinity dynamics. *Irrigation Science* 27(4): 319-330.
- Fufa, F., Grando, S., Kafawin, O., Shakhathreh, Y. and Ceccarelli, S. 2009.** Efficiency of farmers' selection in a participatory barley breeding programme in Jordan. *Plant Breeding* DOI: 10.1111/j.1439-0523.2009.01670.x.
- Galié, A., Hack, B., Manning-Thomas, N., Pape-Christiansen, A., Grando, S. and Ceccarelli, S. 2009.** Evaluating knowledge sharing in research: the international farmers' conference organized at ICARDA. *Knowledge Management for Development Journal* 5(2): 108-126.
- Garg, M., Tanaka, H. and Tsujimoto, H. 2009.** Exploration of Triticeae seed storage proteins for improvement of wheat end-product quality. *Breeding Science* 59(5): 519-528.
- Garg, M., Tanaka, H., Ishikawa, N., Takata, K., Yanaka, M. and Tsujimoto, H. 2009.** A novel pair of HMW glutenin subunits from *Aegilops searsii* improves quality of hexaploid wheat. *Cereal Chemistry* 86(1): 26-32.
- Garg, M., Tanaka, H., Tanaka, N., Takata, K., Yanaka, M. and Tsujimoto, H. 2009.** *Agropyron elongatum* HMW-glutenins have a potential to improve wheat end-product quality through targeted chromosome introgression. *Journal of Cereal Science* 50(3): 358-363.
- Getachew, T., Haile, A., Tibbo, M., Sharma, A.K., Sölkner, J. and Wurzinger, M. 2009.** Morphological characters, body weight and body measurements of Menz and Afar sheep breeds. *Ethiopian Journal of Animal Production* 9(1): 99-115.
- Govindasamy, R., Britel, A., Ariyawardana, A., El-Mourid, M. and Shaqir, I. 2009.** Herbal, aromatic, and medicinal plants industry in Morocco: The way forward. *Icfai University Journal of Agricultural Economics* VI(3&4): 45-55.

- Guo, P., Baum, M., Grando, S., Ceccarelli, S., Bai, G., Li, R., von Korff, M., Varshney, R.K., Graner, A. and Valkoun, J. 2009.** Differentially expressed genes between drought-tolerant and drought-sensitive barley genotypes in response to drought stress during the reproductive stage. *Journal of Experimental Botany* 60(12): 3531-3544.
- Habash, D.Z., Kehel, Z. and Nachit, M.M. 2009.** Genomic approaches for designing durum wheat ready for climate change with a focus on drought. *Journal of Experimental Botany* 60(10): 2805-2815.
- Haile, A., Gashaw, A., Tolemariam, T. and Tibbo, M. 2009.** Epidemiology of nematode parasites of sheep around Jimma, southwestern Ethiopia. *Tropical Animal Health and Production* DOI: 10.1007/s11250-009-9492-7.
- Hamwiah, A., Udupa, S.M., Sarker, A., Jung, C. and Baum, M. 2009.** Development of new microsatellite markers and their application in the analysis of genetic diversity in lentils. *Breeding Science* 59(1): 77-86.
- Hernandez-Segundo, E., Capettini, F., Trethowan, R., van Ginkel, M., Mejia, A., Carballo, A., Crossa, J., Vargas, M. and Balbuena-Melgarejo, A. 2009.** Mega-environment identification for barley based on twenty-seven years of global grain yield data. *Crop Science* 49(5): 1705-1718.
- Ibrikci, H., Ulger, A.C., Korkmaz, K., Oktem, A., Buyuk, G., Ryan, J., Amar, B., Kuluskan, O., Karnez, E., Ozgenturk, G., Cakir, B. and Oguz, H. 2009.** Genotypic responses of corn to phosphorus fertilizer rates in calcareous soils. *Communications in Soil Science and Plant Analysis* 40(9/10): 1418-1435.
- Inagaki, M.N., Mori, M. and Nachit, M.M. 2009.** Effect of a strobilurin-class fungicide on water use under increasing water deficit conditions in synthetic bread wheat genotypes. *Cereal Research Communications* 37(4): 153-159.
- Iniguez, L. and Hilali, M. 2009.** Evaluation of Awassi genotypes for improved milk production in Syria. *Livestock Science* 120(3): 232-239.
- Iniguez, L., Hilali, M., Thomas, D.L. and Jesry, G. 2009.** Udder measurements and milk production in two Awassi sheep genotypes and their crosses. *Journal of Dairy Science* 92(9): 4613-4620.
- Kalra, Y. and Ryan, J. 2009.** Soil and Plant Analysis Council: A model for scientific innovation, education, and development. *Communications in Soil Science and Plant Analysis* 40(17/18): 2639-2657.
- Karam, F., Kabalan, R., Breidi, J., Roupahel, Y. and Oweis, T. 2009.** Yield and water-production functions of two durum wheat cultivars grown under different irrigation and nitrogen regimes. *Agricultural Water Management* 96(4): 603-615.
- Karimov, A., Qadir, M., Noble, A., Vyshpolsky, F. and Anzelm, K. 2009.** Development of magnesium-dominant soils under irrigated agriculture in southern Kazakhstan. *Pedosphere* 19(3): 331-343.
- Kasina, M., Kraemer, M., Martius, C. and Wittmann, D. 2009.** Diversity and activity density of bees visiting crop flowers in Kakamega, Western Kenya. *Journal of Apicultural Research* 48(2): 134-139.
- Kasina, M., Kraemer, M., Martius, C. and Wittmann, D. 2009.** Farmers' knowledge of bees and their natural history in Kakamega district, Kenya. *Journal of Apicultural Research* 48(2): 126-133.
- Katerji, N., Mastrorilli, M., van Hoorn, J.W., Lahmer, F.Z., Hamdy, A. and Oweis, T. 2009.** Durum wheat and barley productivity in saline-drought environments. *European Journal of Agronomy* 31(1): 1-9.
- Khamzina, A., Sommer, R., Lamers, J.P.A. and Vlek, P.L.G. 2009.** Transpiration and early growth of tree plantations established on degraded cropland over shallow saline groundwater table in northwest Uzbekistan. *Agricultural and Forest Meteorology* 149(11): 1865-1874.
- Korkmaz, K., Ibrikci, H., Karnez, E., Buyuk, G., Ryan, J., Ulger, C. and Oguz, H. 2009.** Phosphorus use efficiency of wheat genotypes grown in calcareous soils. *Journal of Plant Nutrition* 32(12): 2094-2106.
- Kumari, S.G., Attar, N., Mustafayev, E. and Akparov, Z. 2009.** First report of *Faba bean necrotic yellows virus* affecting legume crops in Azerbaijan. *Plant Disease* 93(11): 1220.
- Lababidi, S., Mejlhede, N., Rasmussen, S.K., Backes, G., Al-Said, W., Baum, M. and Jahoor, A. 2009.** Identification of barley mutants in the cultivar 'Lux' at the *Dhn* loci through TILLING. *Plant Breeding* 128(4): 332-336.
- Larbi, A., Khatib-Salkini, A., Polus, P. and Iniguez, L. 2009.** Shrub yield and fodder quality variations in a non-tropical dryland environment in West Asia. *Agroforestry Systems* 75(2): 147-155.
- Louhaichi, M., Salkini, A.K. and Petersen, S.L. 2009.** Effect of small ruminant grazing on the plant community characteristics of semiarid Mediterranean ecosystems. *International Journal of Agriculture and Biology* 11(6): 681-689.
- MacCarthy, D.S., Sommer, R. and Vlek, P.L.G. 2009.** Modeling the impacts of contrasting nutrient and residue management practices on grain yield of sorghum (*Sorghum bicolor* (L.) Moench) in a semi-arid region of Ghana using APSIM. *Field Crops Research* 114(2): 53-136.
- Makkouk, K.M. and Kumari, S.G. 2009.** Epidemiology and integrated management of persistently transmitted aphid-borne viruses of legume and cereal crops in West Asia and North Africa. *Virus Research* 141(2): 209-218.

- Medini, M., Baum, M. and Hamza, S. 2009.** Transcript accumulation of putative drought responsive genes in drought-stressed chickpea seedlings. *African Journal of Biotechnology* 8(18): 4441-4449.
- Mohammadi, R. and Amri, A. 2009.** Analysis of genotype x environment interactions for grain yield in durum wheat. *Crop Science* 49(4): 1177-1186.
- Mohammadi, R., Amri, A. and Ansari, Y. 2009.** Biplot analysis of rainfed barley multienvironment trials in Iran. *Agronomy Journal* 101(4): 789-796.
- Mohammadi, R., Amri, A., Haghparast, R., Sadeghzadeh, D., Armion, M. and Ahmadi, M.M. 2009.** Pattern analysis of genotype-by-environment interaction for grain yield in durum wheat. *Journal of Agricultural Science, Cambridge* 147(5): 537-545.
- Murtaza, G., Ghafoor, A., Owens, G., Qadir, M. and Kahlon, U.Z. 2009.** Environmental and economic benefits of saline-sodic soil reclamation using low-quality water and soil amendments in conjunction with a rice-wheat cropping system. *Journal of Agronomy and Crop Science* 195(2): 124-136.
- Nayak, S.N., Balaji, J., Upadhyaya, H.D., Hash, C.T., Kishor, P.B.K., Chattopadhyay, D., Rodriguez, L.M., Blair, M.W., Baum, M., McNally, K., This, D., Hoisington, A.D. and Varshney, R.K. 2009.** Isolation and sequence analysis of DREB2A homologues in three cereal and two legume species. *Plant Science* 177(5): 460-467.
- Ouessar, M., Bruggeman, A., Abdelli, F., Mohtar, R.H., Gabriels, D. and Cornelis, W.M. 2009.** Modelling water-harvesting systems in the arid south of Tunisia using SWAT. *Hydrology and Earth System Sciences* 13(10): 2003-2021.
- Oweis, T. and Hachum, A. 2009.** Optimizing supplemental irrigation: tradeoffs between profitability and sustainability. *Agricultural Water Management* 96(3): 511-516.
- Ozberk, I., Coskun, Y., Ilkhan, A., Koten, M., Karli, B. and Ryan, J. 2009.** Comparison of bed planting-furrow irrigation with conventional planting-flood irrigation in durum wheat (*T. durum* Desf) in Southeastern Turkey. *Pakistan Journal of Biological Sciences* 12(10): 772-778.
- Palmer, R.G., Perez, P.T., Ortiz-Perez, E., Maalouf, F. and Suso, M.J. 2009.** The role of crop-pollinator relationships in breeding for pollinator-friendly legumes: from a breeding perspective. *Euphytica* 170(1-2): 35-52.
- Qadir, M., Noble, A., Qureshi, A.S., Gupta, R.K., Yuldashev, T. and Karimov, A. 2009.** Salt-induced land and water degradation in the Aral Sea basin: A challenge to sustainable agriculture in Central Asia. *Natural Resources Forum* 33(2): 134-149.
- Qureshi, A.S., Oweis, T., Karimi, P. and Porehemmat, J. 2009.** Water productivity of irrigated wheat and maize in the Karkheh River basin of Iran. *Irrigation and Drainage DOI*: 10.1002/ird.481.
- Raman, R., Milgate, A.W., Imtiaz, M., Tan, M.K., Raman, H., Lisle, C., Coombes, N. and Martin, P. 2009.** Molecular mapping and physical location of major gene conferring seedling resistance to *Septoria tritici* blotch in wheat. *Molecular Breeding* 24(2): 153-164.
- Rawashdeh, I.M., Haddad, N. and Amri, A. 2009.** Diversity assessment of *Achillea fragrantissima* (Forsk.) Schultz Bip. populations collected from different ecosystems in Jordan. *Research on Crops Journal* 10(3): 632-642.
- Rawashdeh, I.M., Haddad, N. and Amri, A. 2009.** Genetic relatedness among *Achillea fragrantissima* populations using amplified fragment length polymorphism (AFLP) markers. *Dirasat, Agricultural Sciences* 36(2): 89-99.
- Rawashdeh, I.M., Haddad, N. and Amri, A. 2009.** Morphological diversity among and within populations of a medicinal plant (*Achillea fragrantissima*) collected from different regions of Jordan. *Crop Research* 37(3): 242-254.
- Rosyara, U.R., Ghimire, A.A., Subedi, S. and Sharma, R.C. 2009.** Variation in south Asian wheat germplasm for seedling drought tolerance traits. *Plant Genetic Resources: Characterization and Utilization* 7(1): 88-93.
- Rosyara, U.R., Khadka, K., Subedi, S., Sharma, R.C. and Duveiller, E. 2009.** Field resistance to spot blotch is not associated with undesirable physiological traits in three spring wheat populations. *Journal of Plant Pathology* 91(1): 113-122.
- Rückamp, D., Amelung, W., Simone Borma, L. de., Pena Naval, L. and Martius, C. 2009.** Carbon and nutrient leaching from termite mounds inhabited by primary and secondary termites. *Applied Soil Ecology* 43(1): 159-162.
- Ryan, J., Abdel Monem, M. and Amri, A. 2009.** Nitrogen fertilizer response of some barley varieties in semi-arid conditions in Morocco. *Journal of Agricultural Science and Technology* 11(2): 227-236.
- Ryan, J., Ibrikci, H., Sommer, R. and McNeill, A. 2009.** Nitrogen in rainfed and irrigated cropping systems in the Mediterranean region. *Advances in Agronomy* 104: 53-136.
- Ryan, J., Kapur, S. and Akca, E. 2009.** Application of soil analyses as markers to characterize a Middle Eastern chalcolithic-late bronze age mound. *TUBA-AR-Turkish Academy of Sciences Journal of Archaeology* 12: 65-76.

- Ryan, J., Masri, S., Pala, M. and Singh, M. 2009.** Nutrient dynamics in a long-term cereal-based rotation trial in a Mediterranean environment: Nitrogen forms. *Communications in Soil Science and Plant Analysis* 40(1/6): 931-946.
- Ryan, J., Masri, S. and Singh, M. 2009.** Seasonal changes in soil organic matter and biomass and labile forms of carbon as influenced by crop rotations. *Communications in Soil Science and Plant Analysis* 40(1/6): 188-199.
- Sahile, S., Fininsa, C., Sakhuja, P.K. and Ahmed, S. 2009.** Evaluation of pathogenic isolates in Ethiopia for the control of chocolate spot in faba bean. *African Crop Science Journal* 17(4): 187-197.
- Saifullah, Ghafoor, A. and Qadir, M. 2009.** Lead phytoextraction by wheat in response to the EDTA application method. *International Journal of Phytoremediation* 11(3): 268-282.
- Saifullah, Meers, E., Qadir, M., de Caritat, P., Tack, F.M.G., Du Laing, G. and Zia, M.H. 2009.** EDTA-assisted Pb phytoextraction. *Chemosphere* 74(10): 1279-1291.
- Scheer, C., Wassmann, R., Butterbach-Bahl, K., Lamers, J.P.A. and Martius, C. 2009.** The relationship between N₂O, NO, and N₂ fluxes from fertilized and irrigated dryland soils of the Aral Sea Basin, Uzbekistan. *Plant and Soil* 314(1/2): 273-283.
- Shah, A.S.J., Imtiaz, M. and Hussain, S. 2009.** Phenotypic and molecular characterization of wheat for slow rusting resistance against *Puccinia striiformis* Westend. f.sp. *tritici*. *Journal of Phytopathology* DOI: 10.1111/j.1439-0434.2009.01631.x.
- Singh, I.P., Singh, B.B., Ali, I. and Kumar, S. 2009.** Diversification and evaluation of cytoplasmic nuclear male sterility system in pigeonpea (*Cajanus cajan*). *Indian Journal of Agricultural Sciences* 79(4): 291-294.
- Taye, M., Abebe, G., Gizaw, S., Lemma, S., Mekoya, A. and Tibbo, M. 2009.** Growth performances of Washera sheep under smallholder management systems in Yilmanadensa and Quarit districts of the Amhara National Regional State, Ethiopia. *Tropical Animal Health and Production* DOI: 10.1007/s11250-009-9473-x.
- Thapa, D.B., Sharma, R.C., Mudwari, A., Ortiz-Ferrara, G., Sharma, S., Basnet, R.K., Witcombe, J.R., Virk, D.S. and Joshi, K.D. 2009.** Identifying superior wheat cultivars in participatory research on resource poor farms. *Field Crops Research* 112(2-3): 124-130.
- Thavarajah, D., Thavarajah, P., Sarker, A. and Vandenberg, A. 2009.** Lentils (*Lens culinaris* Medikus subsp. *culinaris*): A whole food for increased iron and zinc intake. *Journal of Agricultural and Food Chemistry* 57(12): 5413-5419.
- Trissi, A.N., El-Bouhssini, M. and Kzaez, A. 2009.** The effect of temperature on some biological characteristics of *Trissolcus vassilievi* Mayer, an egg parasitoid of Sunn pest (*Eurygaster integriceps* Puton.). *Arab Journal of Plant Protection* 27(1): 10-13. [Ar].
- Tubeileh, A., Bruggeman, A. and Turkelboom, F. 2009.** Effect of water harvesting on growth of young olive trees in degraded Syrian dryland. *Environment, Development and Sustainability* 11(5): 1073-1090.
- Von Korff, M., Radovic, S., Choumane, W., Stamati, K., Udupa, S.M., Grando, S., Ceccarelli, S., Mackay, I., Powell, W., Baum, M. and Morgante, M. 2009.** Asymmetric allele-specific expression in relation to developmental variation and drought stress in barley hybrids. *The Plant Journal* 59(1): 14-26.
- White, J.W., Jones, J.W., Porter, C., McMaster, G.S. and Sommer, R. 2009.** Issues of spatial and temporal scale in modeling the effects of field operations on soil properties. *Operational Research: An International Journal* (ORIJ) DOI: 10.1007/s12351-009-0067-1.
- Woldemeskel, M. and Tibbo, M. 2009.** Pulmonary adenomatosis and maedi-visna in Ethiopian central highland sheep: a microscopic study. *Tropical Animal Health and Production* DOI: 10.1007/s11250-009-9520-7.
- Yadata, M.A., Werner, C., Tibbo, M., Wollny, C. and Wicke, M. 2009.** Assessment of the sensory quality and shelf stability of selected Horro beef muscles in Ethiopia. *Meat Science* 83(1): 113-119.

Appendix 2:

ICARDA's Donors and Investors in 2009

Unrestricted Funding

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

Restricted Funding/Grants

- Arab Fund for Economic and Social Development
- Asian Development Bank
- Australian Centre for International Agricultural Research
- Austrian Development Agency
- Authority of Merowi Dam Area for Agricultural Development, Sudan
- Center for Development Research (ZEF), University of Bonn
- CGIAR Gender and Diversity Program
- CGIAR System-wide Genetic Resources Programme

- CGIAR Systemwide Livestock Programme
- CGIAR System-wide Program on Participatory Research and Gender Analysis
- China
- Coca Cola Foundation
- Cornell University
- Development Alternatives Inc
- Egypt - Agricultural Research Center
- European Commission
- Food and Agriculture Organization
- German Federal Ministry for Economic Cooperation and Development (BMZ)
- Global Crop Diversity Trust
- Global Forum on Agricultural Research
- Grain Research and Development Corporation, Australia
- Gulf Cooperation Council
- India
- International Development Research Centre
- International Fund for Agricultural Development
- Iran
- Islamic Development Bank
- Italy
- Japan International Cooperation Agency
- Libya - Agricultural Research Center
- Morocco
- Murdoch University (through ACIAR), Australia
- Netherlands
- Oman
- OPEC Fund for International Development
- Pakistan
- Qatar
- Regional Fund for Agricultural Technology (FONTAGRO)
- Tottori University, Japan
- Turkey
- United Nations Development Programme
- United Nations University Institute for Water, Environment & Health
- World Food Programme
- United States Agency for International Development
- US Department of Agriculture
- World Bank
- World Vegetable Center (AVRDC)

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
- Global Forum on Agricultural Research
- International Atomic Energy Agency
- International Center for Biosaline Agriculture
- International Center for Tropical Agriculture (CIAT)
- International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM)
- International Crops Research Institute for the Semi-Arid Tropics
- International Development Research Center, Canada
- International Food Policy Research Institute
- International Livestock Research Institute
- International Maize and Wheat Improvement Center (CIMMYT)
- International Potato Center (CIP)
- International Rice Research Institute

- International Seed Testing Association
- International Water Management Institute
- 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
- Commonwealth Scientific and Industrial Research Organisation
- 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

- 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

Chile

- Institute of Agricultural Research (INIA)

China

- Chinese Academy of Agricultural Sciences

Denmark

- Danish Institute of Agricultural Sciences
- Riso 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 Zusammenarbeit und Entwicklung (BMZ)
- Deutsche Gesellschaft für Technische Zusammenarbeit (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
- 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 Agroalimentaries (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
- University of Zurich

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

Audited Financial Statements

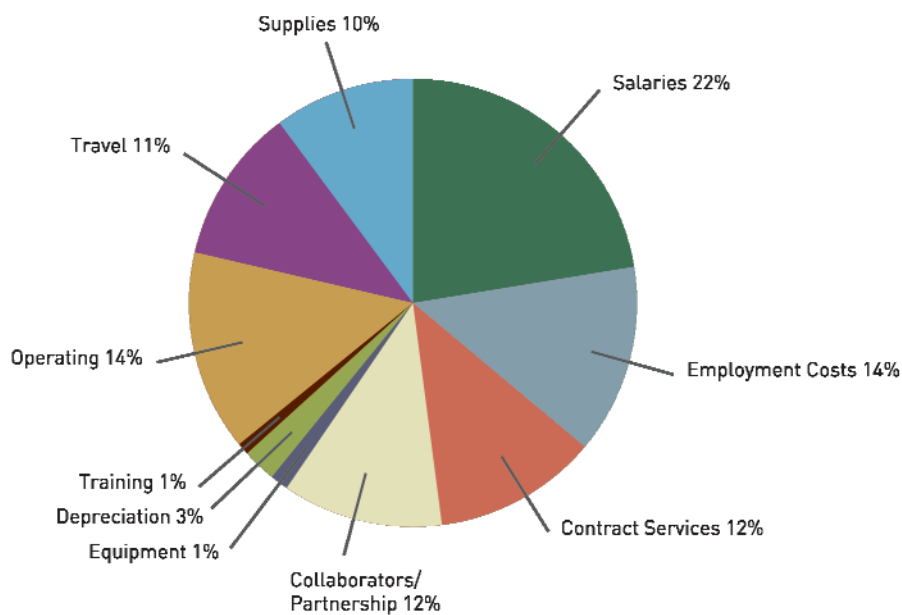
Statement of Activity (US\$x000)		
	2009	2008
REVENUES		
Grants (core and restricted)	31,874	30,243
Other revenues and gains	1,249	1,828
Total revenues and gains	33,123	32,071
EXPENSES AND LOSSES		
Program-related expenses	28,466	27,749
Management and general expenses	5,992	5,335
Other losses and expenses	39	499
Total expenses and losses	34,497	33,583
Indirect cost recovery	(1,924)	(1,416)
Net expenses and losses	32,573	32,167
SURPLUS (DEFICIT)	550	(96)

Statement of Financial Position (US\$x000)		
	2009	2008
ASSETS		
Current assets	41,401	37,451
Property and equipment	3,677	3,091
Other assets	-	-
Total assets	45,078	40,542
LIABILITIES AND ASSETS		
Current liabilities	24,136	20,170
Long-term liabilities	6,899	6,879
Total liabilities	31,035	27,049
Net assets = reserves	14,043	13,493
Total liabilities and net assets	45,078	40,542

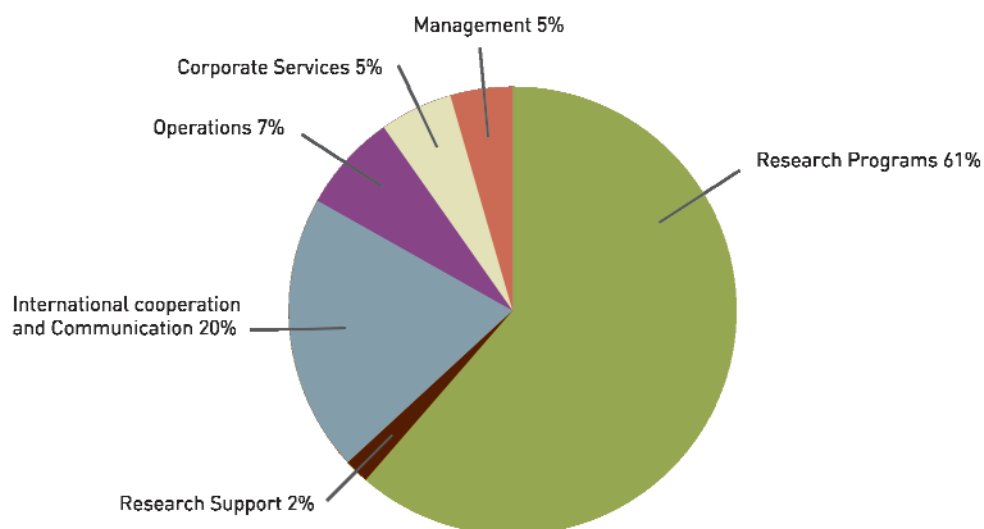
Statement of Grant Revenues 2009 (US\$x000)	
Donors	Amount
Arab Fund	1,255
Asian Development Bank	227
Australia*	2,339
Austria	602
Belgium*	552
Canada*	1,128
CGIAR	886
Challenge Programs	714
Cornell University, USA	954
DAI/USAID	431
Egypt	211
European Commission	1,222
FAO	460
France*	251
Germany*	1,229
Global Crop Diversity Trust	336
Gulf Cooperation Council	691
IDRC	321
IFAD	1,351
India*	395
Iran*	264
Italy*	782
Japan*	322
Libya	3,300
Morocco	308
Norway*	943
Pakistan	396
Qatar	327
Sweden*	541
Switzerland*	405
Syria*	500
The Netherlands*	1,546
United Kingdom*	1,398
United States of America*	2,103
World Bank*	1,568
All others	1,616
TOTAL	31,874

* Donors that provided core funds

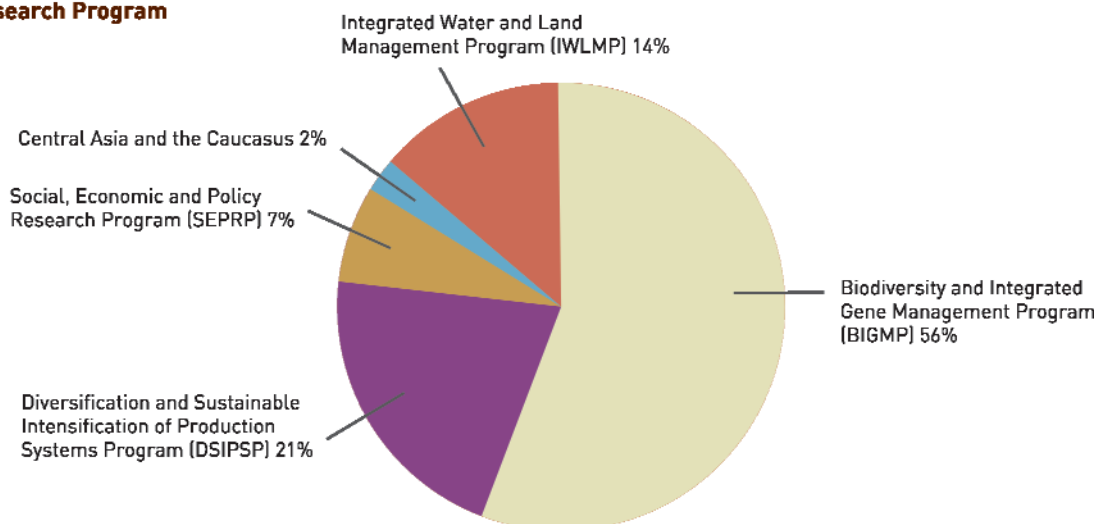
Expenditures by Category



Expenditures by Program and Activity



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 Mohammed S Zehni (Libya), Vice-Chair**

Independent Consultant; Advisor, International Agricultural Studies, Institute of Agriculture, University of Malta
Expertise: plant physiology

Dr Aigul Abugalieva (Kazakhstan)**

Head, Grain Biochemistry & Quality Laboratory, Center for Crop Science and Farming, Kazakhstan
Expertise: biotechnology

Dr Michel A Afram (Lebanon)

President and Director General, Lebanese Agricultural Research Institute
Expertise: agricultural education and policy

Dr Mona Bishay (Egypt)*

Consultant, International Fund for Agricultural Development
Expertise: economics; project/program evaluation

Mr Henri R Carsalade (France)

Former President, Agropolis International, France
Expertise: agronomy

Dr John C Coleman (Canada)

Coleman, Duffett & Associates, Canada
Expertise: international trade, finance and development

Prof Shinobu Inanaga (Japan)**

President, Tottori Institute of Industrial Technology, Japan
Expertise: crop science

Dr Kjersti Larsen (Norway)**

Associate Professor/Head of Department, University Museum of Cultural History, Dept of Ethnography, University of Oslo, Norway
Expertise: social anthropology

Dr David J Sammons (USA)**

Dean, International Center, University of Florida
Expertise: agronomy and crop breeding

Mr Nader Sheikh Ali (Syria)*

Director General, International Cooperation Division, State Planning Commission, Syria
Expertise: economics and planning

Dr Abdelmajid Slama

Consultant
Former Director, Near East and North Africa Division, International Fund for Agricultural Development
Expertise: agronomy and agricultural economics

Dr Mahmoud B Solh (Lebanon)

ex officio
Director General, ICARDA, Syria
Expertise: genetics

Ms Petal Somarsingh (USA)

Principal Financial Management Consultant, Olympus Management, USA
Expertise: management and administration

Dr Paul Steffen (Switzerland)*

Director, Agroscope Reckenholz-Tänikon Research Station ART, Zurich, Switzerland
Expertise: agronomy; research management and policy

Dr Mohammed Walid Tawil (Syria)*

Director General, General Commission for Scientific Agricultural Research, Ministry of Agriculture and Agrarian Reform, Syria
Expertise: agriculture; plant breeding

Dr Camilla Toulmin (United Kingdom)

Director, International Institute for Environment and Development, United Kingdom
Expertise: development economics and climate change

* joined during 2009

** completed term during 2009

Appendix 6: Senior Staff (as of 31 December 2009)

Headquarters – Aleppo, Syria

Director General's Office

Dr Mahmoud Solh, Director General
Mr Ali Abu Hanish, Internal Auditor*
Dr Elizabeth Bailey, Executive Assistant to the Director General and Board Secretary
Mr Michael Mgonja, Internal Auditor *
Ms Houda Nourallah, Administrative Officer – Director General/Board of Trustees
Dr Kamel Shideed, Assistant Director General – International Cooperation and Communication
Dr Maarten van Ginkel, Deputy Director General – Research

Corporate Services

Mr Koen Geerts, Assistant Director General – Corporate Services
Mr Ali Aswad, Consultant for Security, Labor Office**
Mr Frisco Guce, Purchasing and Supplies Manager**
Ms Dalida Nalbandian, Purchasing and Supplies Manager*
Mr Waheed S. Quader, Head, Physical Plant Unit
Mr Nellooli P. Rajasekharan, Director, Human Resources*
Mr Robert Thompson, Head, International School of Aleppo
Mr Mohamad Nabil Traboulsi, Head, Visitors Services and Assistant National Research Coordinator
Ms Lina Yazbek, Coordinator, Human Resources

Finance Department

Mr Bruce Martin Fraser, Director*
Mr Awad Awad, MIS Team Leader**
Miss Anne Wambui Kabuthu, Finance Officer*
Dr Fadil Rida, MIS Applications Specialist
Mr Mohamed Samman, Treasury Supervisor
Mrs Imelda Silang, Accounting Manager

Government Liaison

Dr Majd Jamal, Assistant Director General – Government Liaison*
Dr Ahmed El-Ahmed, Assistant Director General – Government Liaison**

Project Development & Grant Management Unit

Dr Scott Christiansen, Resource Mobilization Facilitator**
Ms Ilona Kononenko, Grants Management Officer

Station Operations

Mr Colin Norwood, Farm Manager
Dr Juergen Diekmann, Farm Manager
Mr Bahij El-Kawas, Senior Supervisor, Horticulture

Beirut Office/Guesthouse, Lebanon

Mr Munir Sughayyar, Executive Manager**

Damascus Office/Guesthouse, Syria

Ms Hana Sharif, Head

Terbol Research Station, Lebanon

Dr Hassan Machlab, Station Manager and Resident Researcher*

Research Programs

Integrated Water and Land Management Program

Dr Theib Oweis, Director
Dr Ahmed Mohammed Al-Wadaey, PDF – Soil and Water Conservation*
Dr Akhtar Ali, Water and Soil Engineer**
Dr Adriana Bruggeman, Agricultural Hydrology Specialist**
Dr Fadi Karam, Irrigation and Water Management Specialist*
Dr Mohammed Karrou, Water and Drought Management Specialist
Mr Venkataramani Govindan, Water Management Communications and Knowledge Sharing Specialist**
Dr Manzoor Qadir, Marginal Water Management Specialist
Dr Rolf Sommer, Soil Fertility Specialist*
Dr Feras Ziadat, Soil Conservation/Land Management Specialist

Biodiversity and Integrated Gene Management Program

Dr Richard Brettell, Director**
Dr Ahmed Amri, Head of Genetic Research Section and Deputy Director, BIGMP
Dr Michael Baum, Acting Director/Biotechnologist
Dr Osman Abdalla El Nour, Bread Wheat Breeder
Dr Zewdie Bishaw, Head, Seed Unit
Dr Shiv Kumar Agrawal, Lentil Breeder*
Dr Akinola Nathaniel Akintunde, ICIS and International Nursery Scientist**
Dr Siham Asaad, Head, Seed Health Laboratory
Dr Mustapha El-Bouhssini, Entomologist
Dr Flavio Capettini, Barley Breeder
Dr Monika Garg, Research Associate*
Dr Stefania Grando, Barley Breeder
Mr Bilal Humeid, Research Associate, Genetic Research Section
Dr Masanori Inagaki, JIRCAS Scientific Representative
Dr Safaa Kumari, Manager of the Virology Laboratory
Mr Jan Konopka, Germplasm Documentation Officer
Dr Muhammad Imtiaz, Chickpea Breeder
Dr Seid-Ahmed Kemal, Pulse Pathologist
Dr Fouad Maalouf, Faba Bean Breeder
Dr Masahiko Mori, PDF Research Fellow**
Dr Miloudi Nachit, Durum Wheat Breeder
Dr Kumarse Nazari, Cereal Pathologist
Mr Abdul Aziz Niane, Research Associate, Seed Unit
Dr Francis D. Ogonnaya, Research Scientist – Bread Wheat Breeding/Biotechnology
Dr Basudeb Sarkar, Barley Breeder**
Dr Kenneth Street, Legume Germplasm Curator
Dr Sripada M. Udupa, Biotechnologist/Geneticist
Dr Amor Yahyaoui, Coordinator, ICARDA-CIMMYT Wheat Improvement Program

Diversification and Sustainable Intensification of Production Systems Program
Dr Barbara Ann Rischkowsky, Acting Director/Senior Livestock Scientist

Appendices

Dr Asamoah Larbi, Pasture and Forage Production Specialist
Dr Mounir Louhaichi, Range Ecology and Management Scientist
Dr Colin Piggan, Project Leader, ACIAR/AusAID Iraq Project
Dr Markos Tibbo Dambi, Small Ruminant Scientist
Ms Monika Zaklouta, Research Associate

Social, Economic and Policy Research Program

Dr Aden Aw-Hassan, Director
Dr Mohamed Abdelwahab Ahmed, Agricultural Policy Specialist
Dr Koffi Nenonene Amegbeto, Agricultural Economist**
Dr Ihtiyor Bobojonov, Agricultural and Policy Economist*
Dr Celine Dutilly-Diane, Visiting Scientist**
Dr Simeon Kaitibie, Applied Agricultural Economist*
Dr Malika Martini Abdelali, Community and Gender Analysis Specialist
Dr Ahmed Mazid, Agricultural Economist
Dr Farouk Shomo, Socio-Economist

Support Services

Capacity Development Unit

Mr Afif Dakermanji, Training Officer

Communication, Documentation, and Information Services

Ms Elizabeth Ann Clarke, Head*
Dr Andrea Pape-Christiansen, Visiting Scientist**
Dr Moyomola Bolarin, Multimedia Training/Material Specialist**
Dr Nihad Maliha, Library and Information Services Manager
Mr Nicholas Martin Pasiecznik, Science Writer/Editor*
Mr Ajay Varadachary, Communication Specialist

Computer and Biometrics Services

Dr Zaid Abdul-Hadi, Head
Mr Hashem Abed, Scientific Databases Specialist
Mr Michael Sarkisian, Senior Systems Engineer
Mr Colin Webster, Senior Network Administrator

Geographic Information Systems Unit

Dr Eddy De Pauw, Head
Mr Wolfgang Goebel, Visiting Scientist
Dr Weicheng Wu, Remote Sensing Specialist

Regional Programs

Arabian Peninsula Regional Program

Dubai, United Arab Emirates
Dr Ahmed Tawfik Moustafa, Regional Coordinator
Dr Abdul Wahid Jasra, Range Ecology and Management Specialist*
Oman, Sultanate of Oman
Dr Mohamed Aaouine, Date Palm Specialist

Central Asia and the Caucasus Regional Program

Tashkent, Uzbekistan
Dr Georg Christopher Martius, Regional Coordinator and Head, CGIAR Program Facilitation Unit**
Dr Zakir Khalikulov, Germplasm Scientist/Liaison Officer
Mr Murat Aitmatov, Research Fellow
Dr Stefanie Christmann, Researcher*
Ms Kirsten Maren Kienzler, Post-Doctoral Fellow*
Dr Nurali Saidov, Research Fellow
Dr Ram C. Sharma, Breeder
Dr Barno Tashpulatova, Research Fellow

Nile Valley & Sub-Saharan Africa Regional Program

Cairo, Egypt
Dr Fawzi Karajeh, Regional Coordinator
Khartoum, Sudan
Dr Hassan El-Awad, Head

North Africa Regional Program

Tunis, Tunisia
Dr Mohammed El-Mourid, Regional Coordinator

South Asia and China Regional Program

New Delhi, India
Dr Ashutosh Sarker, Regional Coordinator and Food Legume Breeder

West Asia Regional Program

Amman, Jordan
Dr Nasri Haddad, Consultant/Regional Coordinator

Highland Regional Network

Tehran, Iran
Dr Mohammad Hassan Roozitalab, Coordinator
Dr Zieaoddin Shoaei, Iran/ICARDA Technical Coordinator*
Kabul, Afghanistan
Dr Syed Javed Hasan Rizvi, Country Manager
Mr Abdul Rahman Manan, Senior Agriculture Advisor
Mr Syed Tehseen Gilani, Administrative and Finance Officer
Islamabad, Pakistan
Dr Abdul Majid, Senior Professional Officer
Ankara, Turkey
Dr Mesut Keser, Consultant

Consultants

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

* Joined in 2009

**Left in 2009

Appendix 7: Abbreviations

ACIAR	Australian Centre for International Agricultural Research	IFPRI	International Food Policy Research Institute
AFESD	Arab Fund for Economic and Social Development	ILRI	International Livestock Research Institute
APRP	Arabian Peninsula Regional Program, ICARDA	INRA	Institut National de la Recherche Agronomique, France
AREEO	Agricultural Research, Education and Extension Organization, Iran	INRA	Institut National de la Recherche Agronomique, Morocco
AusAID	Australian Agency for International Development	INRAA	Institut National de la Recherche Agronomique, Algeria
AVRDC	World Vegetable Center	IPM	Integrated pest management
BIGMP	Biodiversity and Integrated Gene Management Program, ICARDA	IWLMP	Integrated Water and Land Management Program, ICARDA
BMZ	Federal Ministry for Economic Cooperation and Development, Germany	IWMI	International Water Management Institute
BOKU	University of Natural Resources and Applied Life Sciences, Vienna, Austria	IWWIP	International Winter Wheat Improvement Program
CAC	Central Asia and Caucasus	JICA	Japan International Cooperation Agency
CACRP	Central Asia and Caucasus Regional Program, ICARDA	JIRCAS	Japan International Research Center for Agricultural Sciences
CDU	Capacity Development Unit, ICARDA	NARES	National agricultural research and extension systems
CGIAR	Consultative Group on International Agricultural Research	NARP	North Africa Regional Program, ICARDA
CIMMYT	International Maize and Wheat Improvement Center	NARS	National agricultural research systems
CWANA	Central and West Asia and North Africa	NDVI	Normalized Difference Vegetation Index
DSIPSP	Diversification and Sustainable Intensification of Production Systems Program, ICARDA	NGO	Non-governmental organization
DVC	Digital vegetation charting	NVSSARP	Nile Valley and Sub-Saharan Africa Regional Program, ICARDA
ECO	Economic Cooperation Organization	ODAP	Oxalyldiaminopropionic acid
EIAR	Ethiopian Institute of Agricultural Research	OFID	OPEC Fund for International Development
ETH	Swiss Federal Institute of Technology, Zurich	OPEC	Organization of Petroleum Exporting Countries
ETM+	Enhanced thematic mapper plus, Landsat	PGRFA	Plant genetic resources for food and agriculture
FAO	Food and Agriculture Organization of the United Nations	REMS	Rangeland Ecology and Management Section, ICARDA
FIGS	Focused Identification of Germplasm Strategy	SACRP	South Asia and China Regional Program, ICARDA
GEF	Global Environment Facility	SEPRP	Social, Economic and Policy Research Program, ICARDA
GIS	Geographic information systems	SHL	Seed Health Laboratory, ICARDA
GMO	Genetically modified organism	SWOT	Strengths, weaknesses, opportunities, and threats
GRS	Genetic Resources Section, ICARDA	TILLING	Targeting induced local lesions in genomes
GTZ	German Technical Cooperation Agency	Turk-TOB	Turkish Seed Union
ICARDA	International Center for Agricultural Research in the Dry Areas	UAE	United Arab Emirates
ICBA	International Center for Biosaline Agriculture	UNDP	United Nations Development Programme
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics	USAID	United States Agency for International Development
ICT	Information and communications technology	WARP	West Africa Regional Program, ICARDA
IDB	Islamic Development Bank	WLI	Middle East Water and Livelihoods Initiative
IDRC	International Development Research Centre		
IFAD	International Fund for Agricultural Development		



International Center for Agricultural Research in the Dry Areas (ICARDA)

P.O. Box 5466, Aleppo, Syria.

Tel: (+963) (21) 2213433, 2225112, 2225012

E-mail: ICARDA@cgiar.org

Website: <http://www.icarda.org>

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 has a global mandate for the improvement of barley, lentil 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.



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.