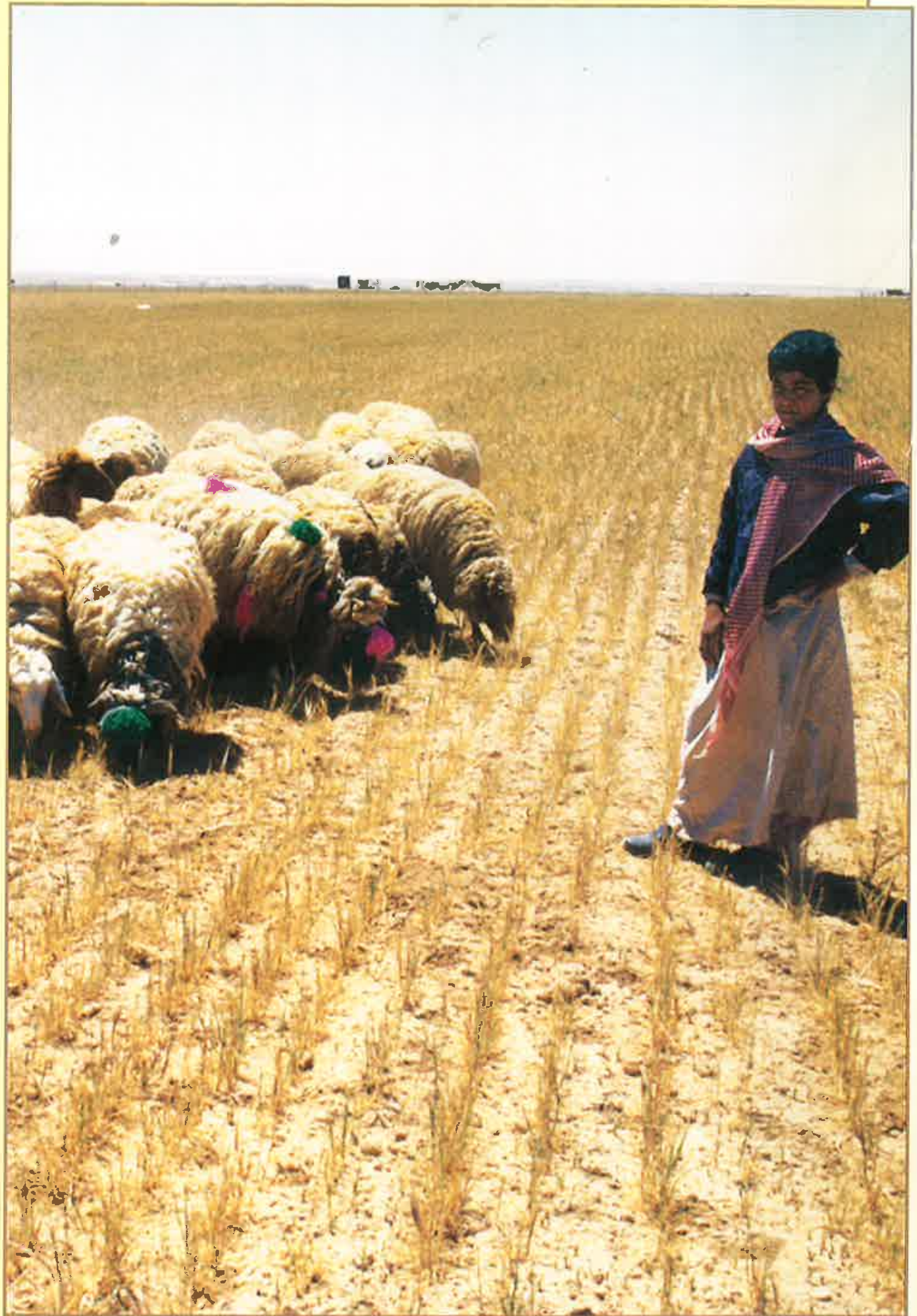
ICARDA Caravan

Issue No. 17, December 2002

Review of agriculture in the dry areas



In this Special Issue on Drought:

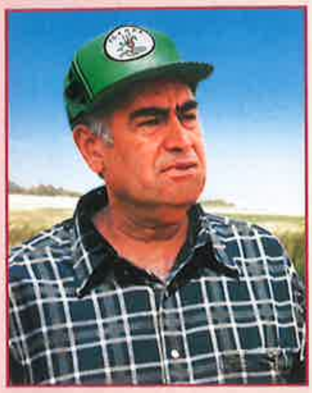
- *Six frequently asked questions about drought*
- *How drought shapes the livelihood strategies of the poor*
- *Better plant and soil nutrition to fight drought*
- *Drought management network*
- *Crop/livestock integration technologies to combat drought and desertification*
- *Drought-tolerant crop varieties*
- *Agrobiodiversity conservation to safeguard genes that can help combat drought*
- *Cross-border seed systems: an insurance against drought*

And more . . .

From the Director General

The word drought conjures images of dry, barren landscapes, and starving people. Developing regions, in Africa and Asia, and specifically ICARDA's mandate area of Central and West Asia and North Africa (CWANA) are most vulnerable to drought.

Although drought hits CWANA countries frequently, it was here that crops were first domesticated in the Near East part of the region, referred to as "the cradle of civilization." Drought has, thus, played a significant role in shaping the destiny of the people in this region. The more than one billion people who live in these areas mostly earn their living from agriculture, using techniques that have evolved over millennia.



Today, the world's dry areas face new challenges, mainly high rates of population growth that stress the environment and strain the capacity of the natural resource base to support them. The Inter-Governmental Panel on Climate Change predicts that the earth's average surface temperature will rise by 1.4 to 5.8 degrees Celsius over the next 100 years. This will result in severe water stress in the arid and semi-arid areas and in decreased agricultural production, particularly in the dry areas, which will become drier and hotter. There is an urgent need for action to mitigate the effects of drought on people, agriculture and the environment, as well as to find ways to cope with it when it comes.

ICARDA, as its name indicates, is the principal international research center dedicated to dryland agriculture. The Center works in close partnership with national agricultural research systems to develop technologies and sound management practices that help farming communities to cope with drought, as well as understand the causes that lead to its occurrence.

This issue of *Caravan* presents the facts about drought, including efforts to more accurately predict its occurrence and severity. Agroclimatologists, for example, are making use of satellite imagery and geographical information systems in their research on combating drought and desertification. Plant breeders, on the other hand, are combining the traditional methods of crossing and selection with the use of biotechnology tools to develop more drought-tolerant crop varieties.

Water-use efficiency is an obvious goal of anyone working in dryland agriculture. We must recognize that water, not land, is the principal factor limiting production, and production systems must be adjusted accordingly. This shift in approach has spawned research into supplementary irrigation and deficit irrigation. The former involves irrigating to maximize production per unit of water; the latter, giving a crop just enough water to produce a satisfactory crop. The water saved can be used to cultivate new land.

ICARDA's research also recognizes the value of local knowledge. After all, it were farmers who first domesticated crops and who, over the ages, have

ICARDA
Caravan

Issue no. 17, December 2002

Cover: When drought hits, there is not enough feed for livestock and the crops fail, so there is no food for humans. Grazing failed crops is not enough for livestock survival, and leaves them starved. Farmers have no choice but to send their animals to slaughter houses. Loss of crop and livestock seriously threatens the livelihood of resource-poor farming families in dry areas.

News

Focus on drought

selected useful traits. A good example of farmer-researcher partnership is the work of ICARDA's barley breeders, who have thoroughly adopted the farmer participatory approach to breeding. Farmers are supplied seeds of potentially useful barley lines and asked to grow them and select the best plants, right on their own farms. The process is more complex than traditional research-station-based breeding, but the result is barley lines that better match farmers' needs and better suit farm conditions.

With more and more countries projected to face increasing water shortages in the coming decades, the need for research and development into drought forecasting and preparedness to protect the productivity of dryland agriculture is obvious. And with water rights so tied to tradition and cross-border relations, all progress on the technological front must move hand-in-hand with progress made on the domestic and international policy front.

Drought is inevitable. But if researchers, farmers, and governments work together, the destruction and suffering that it brings can be reduced and even avoided.

Prof. Dr Adel El-Beltagy
Director General

About ICARDA and the CGIAR

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based at Aleppo, Syria, it is one of 16 centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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

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

CGIAR

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

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

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

Caravan is published twice a year, in June and December, by the International Center for Agricultural Research in the Dry Areas (ICARDA),
P.O. Box 5466, Aleppo, Syria
Tel.: (963-21) 2213433, 2225112, 2225012
Fax: (963-21) 2213490/2225105/2219380
E-Mail: ICARDA@CGIAR.ORG
Web site: http://www.icarda.cgiar.org

Executive editor: Surendra Varma (S.Varma@cgiar.org)
Editor: David Abbass (D.Abbass@cgiar.org)

ISSN 1025-0972

World Summit on Sustainable Development

ICARDA was privileged to have two opportunities to make statements at plenary sessions of the World Summit on Sustainable Development (WSSD) Prof. Dr Adel El-Beltagy (fourth from left, front table), ICARDA DG, made a statement on behalf of the CGIAR at the plenary on 30 August, and another statement at the plenary on 29 August devoted to regional implementation of the WSSD action plan (above).

ICARDA hosted and took part in numerous important meetings in 2002. Among these was the "World Summit on Sustainable Development," held in Johannesburg, South Africa, in August and September. Prof. Dr Adel El-Beltagy represented ICARDA as a CGIAR delegate, and made a presentation in which he highlighted the role of agriculture in improving the quality of life of the poor, in protecting the natural resource base, and in promoting economic growth.

Environmentalists, academicians, and agriculturalists met at ICARDA in May for an international workshop entitled "Desertification: Rehabilitation of Degraded Drylands and Biosphere Reserves."

Environmentalists and agriculturalists joined forces again at ICARDA in May for a workshop entitled "Agriculture, Environment and Human Welfare in West Asia and North Africa." The workshop was organized in cooperation with the International Geosphere Biosphere Program and the International Dryland Development Commission.

The fourth meeting of the Integrated Natural Resource Management (INRM) Task Force of the CGIAR was held at ICARDA headquarters in September. INRM is one of the three pillars of the CGIAR's agenda, along with integrated gene management and information technology.

Donors, researchers, and development administrators met at ICARDA headquarters to consider a draft regional program for sustainable development of rainfed areas of West Asia and North Africa. It was a follow-up to a ministerial meeting held in Rabat, Morocco, in June.

In November, ICARDA was the featured CGIAR Center at the Tri-Society Meeting of the American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA), held in Indianapolis, Indiana, USA. Several ICARDA scientists presented papers and posters. Prof. Dr El-Beltagy was the guest speaker at a special symposium on "Collaborative Strategy to Combat Drought."■

Participants in the "International Workshop on Desertification: Rehabilitation of Degraded Drylands and Biosphere Reserves." The workshop, organized and sponsored by the United Nations Educational, Scientific and Cultural Organization's Programme on Man and the Biosphere; United Nations University; and ICARDA, was held at the Center's headquarters at Tel Hadya on 2-3 May 2002.

Awards for Excellence in Science

King Baudouin Award

Work to develop high-yielding kabuli chickpea varieties that thrive in cool, wet winter conditions earned for ICARDA the 2002 King Baudouin Award from the Consultative Group on International Agricultural Research (CGIAR), jointly with its sister center, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which focuses its research on desi chickpea. The award was presented to the two centers by the CGIAR Chairman, Dr Ian Johnson, at the Annual General Meeting of the CGIAR in Manila, Philippines, in October 2002.■

Prof. Dr Adel El-Beltagy (right), ICARDA DG; Dr William Dar (left) ICRISAT DG; and Dr Jagdish Kumar, Principal Chickpea Breeder, ICRISAT, received the King Baudouin Award from the CGIAR Chair, Dr Ian Johnson (second from right).

Other Honors and Awards

- ICARDA's Director General, Prof. Dr Adel El-Beltagy, was elected Academician (Foreign Member) of the Tajik Academy of Agricultural Sciences in the field of crop science.
- Dr Rajendra S. Paroda, Regional Coordinator of ICARDA's Program for Central Asia and the Caucasus (CAC) and Head of the Program Facilitation Unit of the CGIAR Program for CAC, was elected Fellow of the Georgian Academy of Agricultural Sciences and Armenian Academy of Agricultural Sciences, and Academician of the Tajik Academy of Agricultural Sciences; and won the B.P. Pal Memorial Award for the Biennium 2001–2002 of the National Academy of Agricultural Sciences (NAAS), India. Dr Paroda was also honored by the ICRISAT Board of Trustees and Management. In December 2002, the Institute's prestigious germplasm repository was named the Rajendra S. Paroda Genebank, in recognition of his outstanding contributions to genetic resources conservation.
- In June 2002, His Majesty the King of Morocco, Mohamed VI, conferred the royal medal "Chevalier d'Honneur" on Dr Miloudi Nachit, CIMMYT/ ICARDA Durum Wheat Breeder, for his research on durum wheat improvement in the Mediterranean region.
- Dr Miloudi Nachit, Dr Mustapha El-Bohssini, Entomologist, and Dr Ahmed Amri, Coordinator, Regional Agrobiodiversity Project, shared with Drs N. Nserallah and S. Lhaloui of the Institut National de la Recherche Agronomique, Morocco, the 2002 Prize for Research and Development in Morocco.
- Dr Mustapha El-Bohssini shared with Mr K. Mardini, Agricultural Research Center, Aleppo, and Dr Adnan Babi, University of Aleppo, the 2002 Basel Award for Scientific Agricultural Research in Syria.
- At the International Soil Science Congress, held in Bangkok, Thailand, in August, Dr John Ryan, Soil Fertility Specialist, was elected Commission Chairman for Soil Fertility and Plant Nutrition, of the International Union of Soil Scientists.■

H.E. Mr Tursunboi Rakhmatov (center), Minister of Agriculture, and Academician Bobo Sanginov, President of the Tajik Academy of Agricultural Sciences, decorate the ICARDA Director General with robe and hat to mark his induction as the first foreign member of the Academy.

Drought in WANA: Six Frequently Asked Questions

To successfully address the challenge of drought, researchers and agriculturists must first understand this complex phenomenon. That's where agroclimatologists can help. The following are the answers to six frequently asked questions about drought to better understand the work being done by ICARDA to improve nutrition and income of the people who live in drought-prone areas.

By Eddy De-Pauw

Is drought unusual?

Drought is persistent below-normal precipitation. Wherever precipitation varies significantly from year to year, droughts are to be expected. For this reason, drought is not confined to low-rainfall areas. Higher rainfall areas can experience drought, and, in terms of absolute fluctuations, often more than low-rainfall areas (Figure 1). Droughts do vary, however, in severity, area affected, and impact. The West Asia and North Africa (WANA) region, which is 57% hyper-arid and 21% arid (Figure 2), is particularly vulnerable to drought.

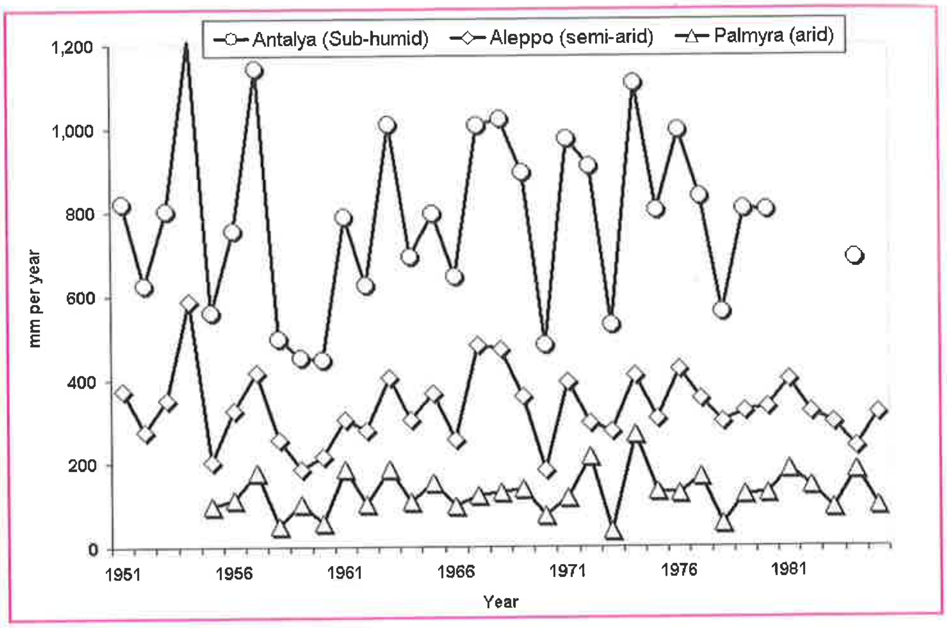


Figure 1. Precipitation fluctuations 1951-1985 for three stations under different moisture regimes.

What is the impact of drought?

The impact of drought depends on its extent and severity, and a society's capacity to respond. The direct effects are reduced agricultural productivity due to declines in planted area and yield, and poverty for farmers and livestock owners. Rainfed crops are especially affected (Figure 3) by large production fluctuations, but irrigated crops also can suffer during severe droughts when reservoirs are unable to provide sufficient water. Indirect effects include added pressure on urban resources by migration of rural people, and accelerated desertification of marginal lands. For governments it can create balance payment problems, either due to declining agricultural export earnings or the need for additional imports.

The patterns of drought in WANA are extremely variable in their spatial and temporal dimensions. Some droughts are severe enough to affect the entire region, from Morocco to Iran

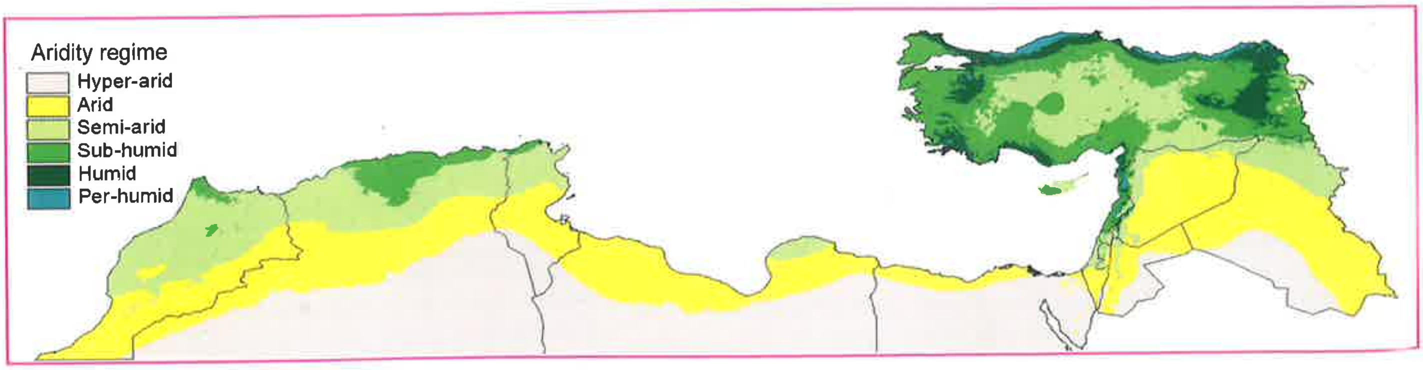


Figure 2. Aridity regimes in the WANA region.

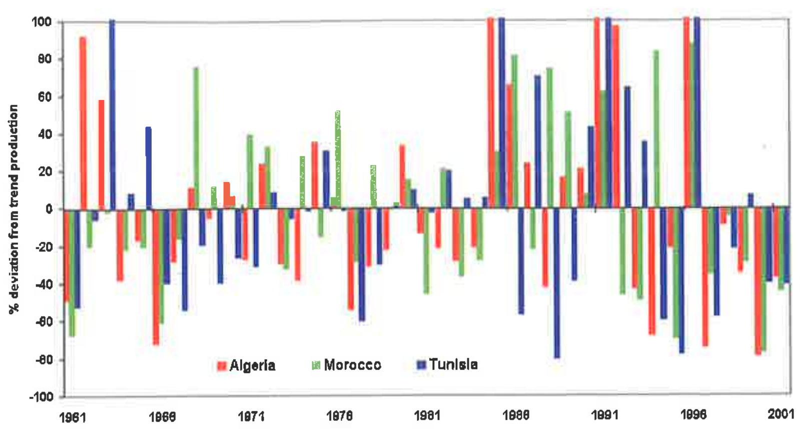


Figure 3. Relative production fluctuations of barley in the Maghreb countries (data source: FAOSTAT).

and well beyond, into Afghanistan and Tajikistan. Yet, droughts can also be very local in scale. Syria's drought of 1999 led to a severe decline in the productivity of rangeland and barley area on the steppe margins. This continued for several years. The drought, however, had relatively little effect on the production of wheat and tree crops in the higher rainfall areas, which recovered from 2000 onwards.

Are droughts predictable?

Droughts cannot be predicted, but only forecast. Forecasts are statements about possible outcomes based on probabilities. For example, a seasonal rainfall forecast is essentially an estimate of the probability that rainfall will be above or below average or about average. In many parts of the world, the El Niño Southern Oscillation (ENSO), a global ocean-atmosphere-coupled weather pattern, is used as an indicator of rainfall patterns for the coming crop growing season. While it is certainly useful to have some indication of possible future weather in one place based on current weather in another, there are difficulties in translating forecasts derived from ENSO into specific management recommendations for farmers. Another problem, given the very large scale of the potential impact area of ENSO, lies in predicting what areas will be affected and fine-tuning forecasts to match the complexity of farming systems, particularly in developing countries. Yet, no clear relationships between drought in WANA and ENSO events have been established, and, in fact, rainfall patterns in the region are controlled by other global weather oscillations, such as the North Atlantic Oscillation (NAO), unfortunately without predictive potential.

Will climate change make droughts worse?

The short answer is 'yes.' On the basis of Global Circulation Model (GCM) simulations, the Intergovernmental Panel on Climate Change (IPCC) projects for the region small increases in precipitation, but these increases are likely to be countered by increased temperature and evaporation, and drought is likely to increase.

The long answer is more ambiguous. First, the scale at which GCMs operate is too large to capture the effects of local topography on weather systems. Second, much depends on the time of the year when the projected changes in temperature and precipitation occur. Increases in temperature and precipitation during the colder part of the year could, for example, enhance growing seasons.

How can societies best respond to drought?

The usual response to drought is crisis management—solving problems as they arise. This approach might seem pragmatic, but during severe droughts it is also very costly in economic and social terms, especially at the level of the individual and community. Ideally, societies in dryland areas should plan for drought within the context of a comprehensive dryland management vision. This means treating drought as a natural but manageable problem in long-term development plans. This requires policies and management plans that integrate the dimensions of agricultural production stabilization and enhancement and environmental sustainability, and a more holistic vision of the contribution of agricultural research.

What drought research is most needed?

Improving the value of drought forecasting for the WANA region should be made a research priority. Drought forecasting is mostly unsuccessful in the region, due to the interaction of meteorological systems from the Atlantic Ocean, Persian Gulf, and Caspian Sea. In the first place, it is necessary to detect the signals that are hidden in the climatic data of the past. This requires collaboration and data sharing among meteorological organizations. Such collaboration remains limited. Research on the potential of using meteorological satellites for identifying, characterizing, and monitoring atmospheric water sources and precipitation events could also help in long-range forecasting.

Remote sensing for the monitoring and mapping of drought is another potentially important research area. Meteorological and other satellite systems can generate, at global and regional scales, a range of indicators related to vegetation health. These are already used in several early-warning systems to forecast crop condition and estimate agricultural production.

Drought has meteorological, agricultural, hydrological, and socioeconomic dimensions. Different indicators and information sources are needed to assess different characteristics of drought, such as

Continued on page 10

Plant Nutrition and Agronomic Practices: Prerequisites for Drought Mitigation

The public perception of drought is one of starving masses, emaciated ruminants, withering crops in the field, parched landscapes, and relief agencies struggling to cope. The history of drought is as old as that of human civilization; indeed, drought has played a major role in shaping the destiny of the people of the Near East, the cradle of civilization. Despite modern advances, the specter of drought still stalks almost all continents, with the exception of Europe and other temperate areas. Developing regions, in Africa and Asia for example, and specifically ICARDA's mandate area of West Asia and North Africa (WANA), are most vulnerable. This raises urgent questions about the causes of drought and what action can be taken to eliminate or at least reduce its impact on people, agriculture, and the environment.

By John Ryan and Mustafa Pala

Drought Solutions: Elimination or Adaptation

In considering the causes of drought, we first think of rainfall insufficient to sustain crop growth, or insufficient irrigation water to grow crops in areas where rainfall is normally inadequate. The picture is, in reality, more complicated than that. We need to ask the question, can we change the causes of drought, or is it something we have to live with. Unfortunately, humans have little influence on rainfall. Cloud seeding to induce rain holds little hope of making dry areas less dry. Indeed, if we are to believe climatologists and environmentalists, we are facing a future in which much of the world will have *less*, rather than *more*, rain. One of the obvious means of mitigating drought and making up for shortfalls in rain is through irrigation, a strategy that has been used for millennia. While there have been spectacular increases in crop yields with irrigation, and there have been developments in irrigation technology in order to improve the efficiency of water use, grim reality is that water for irrigation is not likely to increase in the future. Limits in many cases have been reached. Declining groundwater levels due to over-pumping is a cause for alarm, and while surface waters, mainly rivers, have reached their capacity, agriculture will have to share a static or diminishing water supply, strained by ever-growing urban, industrial, and recreational demand.

Thus, the only viable alternative is to cope with drought, and come to terms with the reality of a limited water supply and rising human needs. But there is hope. The more we know about drought, the better we can predict its occurrence, and better deal with its consequences. But the main source of optimism stems from the observation that some plant species are able to survive low-rainfall conditions and periods of severe drought. Plant breeders and biotechnologists have achieved considerable success in exploiting this genetic potential in developing drought resistant and tolerant crop varieties. Associated with this "war on drought," is a more basic strategy – one that does not attract headlines – that involves maintaining optimum conditions for crop production through adequate nutrition and appropriate soil and crop management. Borrowing an analogy from medicine, the objective is to provide good nutrition to ward off diseases and ensure health and well-being.

Soil Fertility and Fertilization

Soil is the main source of nutrients for crop growth. Prior to the chemical fertilizer age, soil was virtually the only nutrient source, except where manures were available. Apart from nutrients, soil also provides additional physiological benefits in terms of drought, cold, and disease resistance. The soil also dictates crop quality and provides nutrients that are not needed for plant growth but nevertheless impact the end-users, i.e., humans and animals. The soil is rarely the perfect medium to meet all of the plant's nutritional needs. Fertilization is modern science's attempt to supplement the deficiencies of nature.

Like soils in other regions of the world, the soils in Central and West Asia and North Africa (CWANA) exhibit a

Response of barley in Chaouia, Morocco, to increased N levels (0, 40, 80, 120 kg/ha) under moisture-stressed conditions (350 mm/yr).

diversity of soil types of varying fertility. In general, virtually all soils have inadequate supplies of nitrogen (N) to sustain modern crop yields and to ensure adequate protein levels in the produce. The example from the semi-arid area of Chaouia in Morocco shows that barley yields can be dramatically increased by application of N fertilizer, even in years of drought. Research in WANA has shown that nutrients rather than available moisture are the main constraint; addition of fertilizer generally increases yield in all but the most severely drought-limited conditions. However, excess N should be avoided under such conditions as it causes rapid vegetative growth, in excess of the moisture supply in mid to late spring, and results in low grain yield.

Phosphorus (P), the second of the major elements required by plants, is widely deficient in the soils of WANA. Unlike N, use efficiency of P is low because of adverse soil reactions. Banding of P—placing the fertilizer in the soil at the base of each plant—has improved efficiency greatly, but it remains low, with 10–15 % of applied P used by the crop in any one season. While P deficiency was more severe in the past, as illustrated by field response from Pakistan with the application of superphosphate, routine fertilization has resulted in a buildup of available P in soils to the extent that responses are lower than before, and now less P fertilizer is needed in many places.

While potassium (K) is the third major element required by crops, soils in West Asia, and in drylands in general, are well supplied with this element, and only limited K fertilization is needed, except on sandy soils and with high K-demanding crops, such as sugarbeet and potatoes. While little is known about other possible growth-limiting nutrients in WANA soils, such as micronutrients iron and zinc, there are indications of severe constraints in some areas. When deficiencies are identified and rectified, the impact of drought can be reduced. Another micronutrient, boron, can reduce yield when deficient, or become toxic under drought conditions.

Physiology and Water-Use Efficiency

While the soil and the added fertilizer might provide adequate nutrition for the physiological functioning and growth of plants, nutrients can confer additional indirect benefits to crops, enabling them to cope with their environment. There is evidence that K not only improves water relations in plants and thus resistance to drought, but also increases disease resistance. Boron has a similar additional effect on physiological processes. Research at ICARDA and elsewhere has shown that P fertilizer, especially when banded, has a stimulating effect on root growth, and helps the plants to exploit subsoil moisture reserves leading to better crop establishment, earlier maturity, and higher yield even in moisture-stressed environments.

In rainfed semi-arid conditions, the goal of soil fertility and agronomic management is to optimize the efficient use of water and thus mitigate drought effects, which in WANA invariably occur at the end of the growing period in the late spring, so-called terminal drought. Fertilization, apart from increasing crop yield, also ensures higher water-use efficiency.

Response of wheat in Potahar plateau, Pakistan, to application of superphosphate (<300 mm/yr).

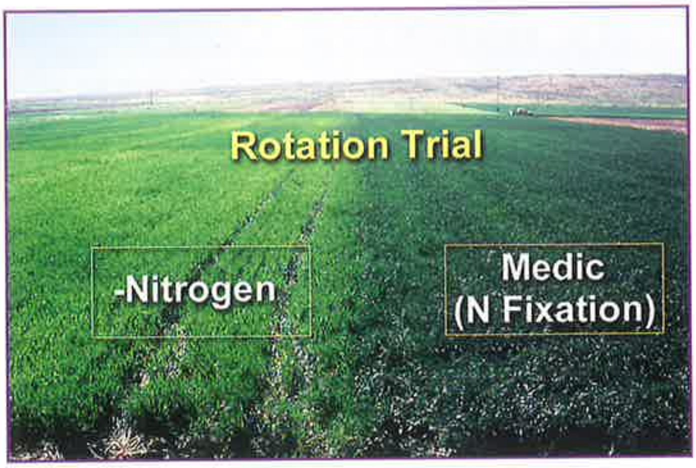
Agronomic Practices

Agronomy is the science of managing a growing crop in the field, and as such is complementary to the science of soil fertility and plant nutrition. Though arguably less glamorous than other areas of plant science, agronomy has contributed enormously to crop and food production worldwide. Simple, inexpensive practices have made positive impact at the farmer's level, particularly in developing countries.

Success of any agronomic research/technology transfer process begins with assessing improved varieties produced by breeders and matching them with management practices. Despite the vagaries of weather in the early part of the crop season (October–December), early sowing invariably produces good stand establishment and yield, regardless of the moisture stress. A key factor in agronomy has been the balancing of plants' needs with available moisture. Thus, optimum planting densities (along with row spacing) have been established for the various crops in WANA. Similarly, as weeds compete with crops for available moisture – and thus exacerbate drought – the importance of weed control, whether chemical or mechanical, is obvious. Other practices that impact directly or indirectly on water use include legume-based rotations as a substitute for fallow and cereal monoculture and conservation tillage, as opposed to conventional tillage.

Link with Global Warming

Much has been written about the role of greenhouse gases, especially carbon dioxide, in contributing to global warming and drought. Relatively little has been said, however, about agronomy's role in providing at least a partial solution to the problem. Research at ICARDA, unique in Mediterranean-type regions, has shown that cereal rotations with legumes, such



Influence of medic in rotation with wheat at Tel Hadya, Syria; medic plot on right has better growth and higher N status due to N fixation by the crop (rainfall: 330 mm/yr).

as vetch and medic, could lead to a substantial increase in soil organic matter, thus leading to the "sequestering" of carbon dioxide and its incorporation into the soil, where it benefits soil physical properties and improves soil moisture relations and soil biological conditions. Early indications suggest that conservation tillage could also help reduce levels of atmospheric carbon dioxide. In short, good agronomic practices equate to good environmental sense.

Fundamental Contribution

Soil fertility and agronomic management are fundamental factors in the agriculture of developing and developed countries alike, and research in these fields has been instrumental in feeding the world's growing population. Drought has been a scourge of mankind in the past and will continue to be so in the future. Science will continue to work to mitigate its effects, with due consideration to the important role played by adequate plant nutrition and sound agronomic management. ■

Dr John Ryan (J.Ryan@cgiar.org) is a Soil Fertility Specialist and Dr Mustafa Pala (M.Pala@cgiar.org) is a Wheat-based-Systems Agronomist at ICARDA.

Six Frequently Asked Questions

Continued from page 7

intensity, exceptionality, impact, and spatial extent of each dimension. Dedicated early warning systems are required to bring all possible information sources together in a cohesive and holistic way. Geographical information systems are particularly suited for this task given their ability to link every item of information to a given location.

Mapping hot spots of drought vulnerability is very useful for drought planning. It is now feasible to analyze through remote sensing the response of vegetation to weather fluctuations, from year to year, over very large areas at a reasonable spatial resolution. This makes it possible to identify areas most sensitive to drought (Figure 4).

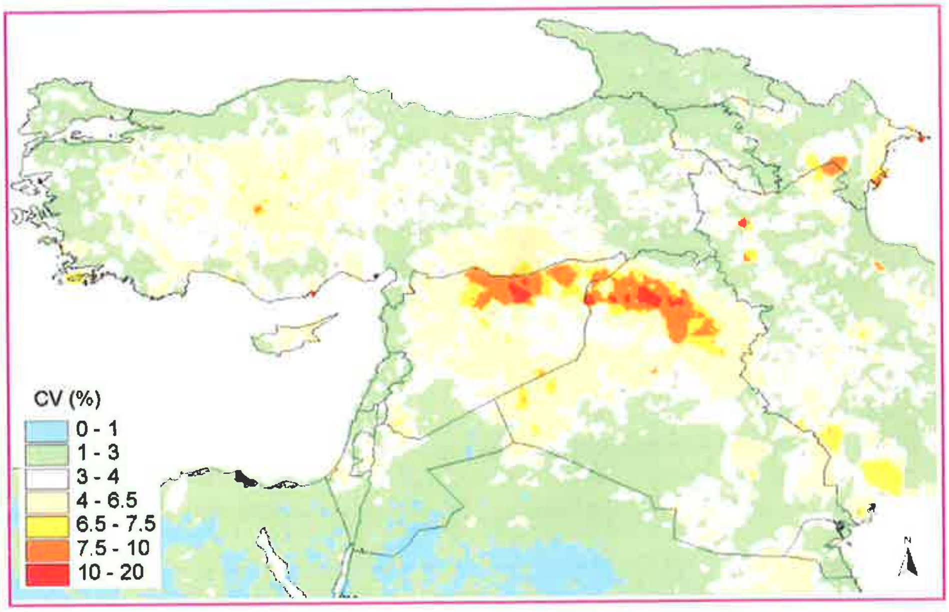


Figure 4. Spatial distribution of drought vulnerability in West Asia.

Drought is a natural phenomenon

To combat drought effectively, it must first be recognized and accepted that drought is an entirely natural phenomenon of dryland environments. Once this is understood, it becomes clear that the most effective buffering against drought is through application of proven dryland management principles. This would translate, for example, into not growing crops in marginal environments, in reducing water consumption, in grazing rangelands according to their carrying capacity. The role of the agroclimatologist in this wider context of drought planning is modest, but certainly important. There is much scope for improved climate forecasts in the region, which could lead to timely advice to farmers on how to plan for the coming growing season. There is also great need to monitor drought as it evolves and help decision-makers target assistance to the most affected or vulnerable areas. ■

Dr Eddy De-Pauw (E. de-Pauw@cgiar.org is an Agroclimatologist at ICARDA.

International Network to Help Countries Cope with Drought

The severe droughts that affected West Asia and North Africa in the last few decades highlighted the need for appropriate drought mitigation measures. This requires the identification of effective approaches and the application of useful tools, such as models and decision support systems, to help policy makers improve the response to drought events. To help address the challenge of drought on a broad scale, governments, agencies, and institutes, including ICARDA, have established the Network on Drought Management for the Near East, Mediterranean and Central Asia (NEMEDCA Drought Network).

By Theib Oweis

Management of scarce natural resources, such as water, lies at the heart of drought preparedness and mitigation. ICARDA has, since its inception, been working to alleviate the effects of drought by developing crop varieties that can withstand drought, and by researching cultural practices that improve water-use efficiency. For example, in partnership with institutions in Italy, Portugal, Tunisia and Jordan, the Center helped develop a decision support system to reduce the effects of drought in the Mediterranean region. This effort was supported by the European Union.

The Food and Agriculture Organization of the United Nations (FAO), the International Center for Advanced Study on Mediterranean Agriculture (CIHEAM), and several other organizations also carry out important work on drought mitigation in the Near East and the Mediterranean region. They joined ICARDA for a workshop at the Center's headquarters in May 2001, which laid out the basis for drafting national plans of action and regional strategies for drought mitigation. A follow-up meeting later in that year resulted in a detailed proposal for a network that was to become NEMEDCA Drought Network.

Now established, the countries served by the network include: Algeria, Libya, Mauritania, Morocco, and Tunisia (North Africa); Djibouti, Egypt, Eritrea, Ethiopia, Somalia, and Sudan (the Nile Valley and the Red Sea); Cyprus, Iraq, Jordan, Lebanon, Palestine, Syria, and Turkey (West Asia); Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates, and Yemen (Arabian Peninsula); and Islamic Republic of Iran, Kazakhstan, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan (Central Asia).

The objective of the network is to enhance the exchange of information and experience among national, regional, and international organizations. Specific objectives include:

- Promoting risk, vulnerability, and impact assessment of drought, considering ecological, agricultural, and socioeconomic dimensions at the national and regional level
- Contributing to the creation, development, and coordination of drought preparedness and mitigation plans, including harmonization of methodologies and approaches used in member countries

Continued on page 22

Participants in the "Drought Mitigation in the Near East and the Mediterranean" workshop, held at ICARDA 27-31 May.

Understanding Poverty and Development Options in Dry Areas: The Khanasser Valley Integrated Research Site in Syria

By Aden Aw-Hassan, Ahmed Mazid and Roberto La Rovere

Communities in dry areas with marginal and degraded land resources are among the poorest of rural communities. Their livelihoods are affected by the risks inherent in dryland farming. The scant public services further affect their welfare. Agricultural research systems are challenged in helping to develop these communities. ICARDA has selected a benchmark site in the Khanasser valley, about 70 km from Aleppo city in northwestern Syria. It is a marginal area (200–250 mm annual rainfall) where people eke out a living from growing barley and raising sheep, and is an ideal place to test the integrated natural resources management (INRM) approach as a way of improving rural livelihoods and promoting sustainable use of natural resources.

The Khanasser Valley Integrated Research Site (KVIRS) is in a transitional zone between the steppe and agricultural land. The valley is home to about 17,800 people, in 1814 resident households in 31 villages of different sizes. The population density works out to 93 people/km^2.

Methodology

Key issues at the watershed scale were characterized using a rapid rural appraisal (RRA) methodology that included semi-structured surveys and conversational interviews with key informants in each village in summer of 2001.

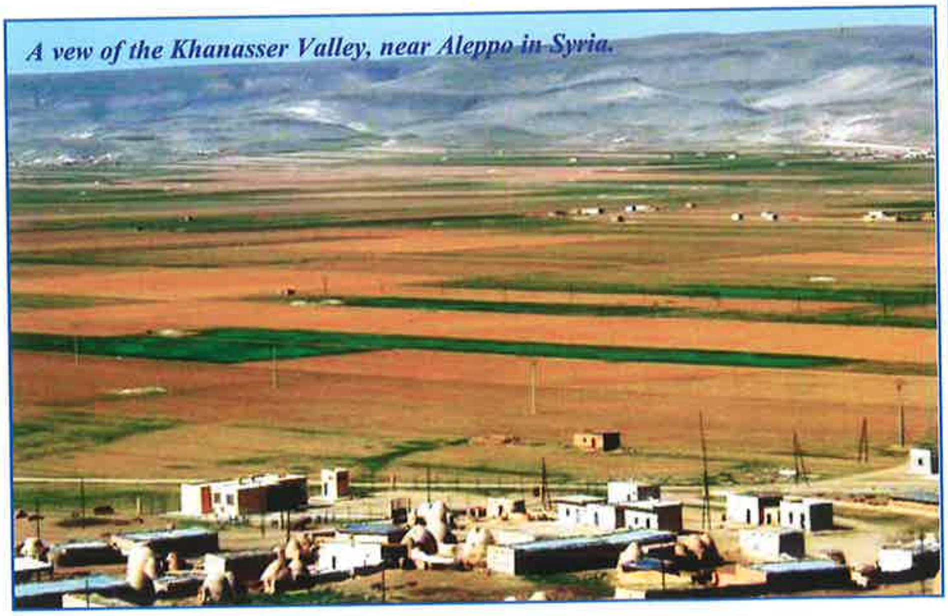
Well-being indicators

Rural well-being indicators, which include household assets, access to asset building capital and basic infrastructure, are described below:

Access to services: About 65% had elementary schooling. The number of girls attending elementary school is half that of boys. Only 7% of those who finish elementary school go on to middle school, with girls less likely to move on than boys. Seasonal migration of households in pursuit of wage labor is a major constraint to school attendance. Investment in education, in addition to agricultural research and roads, is effective poverty reduction policy.

Land Resources: Some 16,000 hectares are cultivable. A quarter of the cultivable land is fallow at any given time. Individual holdings are small and almost entirely rainfed. Communities have free access to about 4860 ha of degraded rangeland (23% of total land), mainly on the hills surrounding the valley. About 39% of the land is privately owned, 31% was acquired through the land reform program implemented since 1958 with incomplete property rights, and 30% is state land comprising leased cultivated and open access rangeland. About 15 % of households own no land.

Based on natural, physical, financial, and human capital, about 13% of the households were classified as very poor, 48% poor, 33% moderately better off, and only 6% well off. Key informants did not mention explicitly social capital as a well-being indicator, as this is embedded naturally in the formation of other capitals.



A vew of the Khanasser Valley, near Aleppo in Syria.

Livelihood strategies

Crop production

Rainfed barley is the principal crop, accounting for about 65% of cultivated land. It is adapted to dry environments and has good feed value. Wheat is cultivated in limited areas (6%), mainly for household consumption.

There is growing interest in cumin as a cash crop.

In some villages, well owners irrigate small plots of cash crops, such as cotton, vegetables, barley and wheat. About 1% of the cultivated area is irrigated in summer. Intensive pumping has depleted groundwater and deteriorated water quality. Thus, irrigation is now limited to a small area. Well owners also sell water. Planting of fruit trees, mainly olives, is slowly expanding. Some 74% of the communities are in favor of fruit tree planting because of perceived higher returns than from barley.

Extensive sheep production

With 28,000 sheep and about 1300 goats reported in the valley, and about 70% of households owning livestock, sheep production holds an important livelihood function; however, the size limits for a profitable flock need to be determined.

Sheep fattening

Sheep fattening, based entirely on hand feeding, is a new but increasingly important activity. In this highly specialized intensive system, producers buy lambs supplied by the extensive production system, then fatten and sell them. Some 15% of households rely on the practice for quick profit.

Straw trade

Straw is an important income earner for some households that move to irrigated or wetter areas after harvesting their crops. They rent wheat fields with crop residues, collect straw for their animals, and sell surplus straw to traders.

Off-farm employment

Off-farm employment in the agricultural sector in more favorable areas, in cities, and outside the country is an important livelihood strategy in the valley. About 53% of households in Khanasser valley have members who are off-farm wage laborers, 20% of households have members who are wage laborers in cities, and 13% have members who labor outside Syria.

Classification of communities

Eleven variables were used in a cluster analysis: number of households resident in the village; total village area; total rangeland area; road type; percentage of households having electricity; number of farmers owning a tractor; availability of elementary school; number of households working as off-farm wage laborers; number of households working outside Syria; and number of farmers fattening sheep in the community. Three clusters of villages with broadly similar livelihoods were identified.

Options for improving the livelihood of the poor

Discussions with farmers highlighted the following options and factors that appear to influence farmers' acceptance:

About 53% households in Khanasser valley have members who are wage laborers.

Improving the barley/livestock system

Drought tolerant high performing barley varieties suitable for Khanasser conditions could reduce risk and increase income. A farmer participatory breeding program has been initiated.

Alley cropping of drought resistant atriplex shrubs with barley, introduced in 1996, could increase availability of nutritious feed, particularly during drought years. Most villages (70%), however, have rejected this technology. The reasons are being investigated.

Improved flock management for dairy sheep and small-scale village facilities for handling and processing quality milk products could have a high payoff. This will depend, however, on factors such as suitable flock size, feed cost, and milk prices.

Improved practices of new crops

Improved water-harvesting techniques can enhance the productivity and profitability of olive trees, particularly, if it reduces the irrigation cost during the harsh summer months. Profitability also depends, however, on prices, and given the expected increase in olive production in Syria as plantations reach peak output, prices will fall unless exports increase substantially. This requires an effective export strategy that includes adoption of improved oil extraction technology, improved quality control, and improved marketing skills.

Production of cash crops, such as cumin, can have high returns, but is risky due to low and variable rainfall and market fluctuations.

Value-added enterprises

Sheep fattening is profitable, but lack of financial capital bars entry into the business for many people. Institutional

Livestock plays a key role in the livelihood strategies of the Khanasser valley residents.

innovation, such as micro-credit, could enable the poor to access the necessary capital. The informal credit sector charges up to 30% interest.

Small-scale added value enterprises, such as production of capers, medicinal plants and mushrooms, might have profit potential, but there is limited information on which to draw clear conclusions.

The landscape of the valley is suited to the building of micro-dams for limited irrigation, for example, of vegetables. Development of small dams should, however, take into consideration the effects on downstream users. For this reason, participation of stakeholders in planning, development, and management is critical for their sustainable use.

Ecotourism

The villages of the valley, with their unique traditional beehive houses, the ancient subsurface water channels (*qanats*) and a nearby salty lake, with its wild life and unique ecosystem, together represent an opportunity for ecotourism. Development of ecotourism would require, however, that local communities learn more about such enterprises and gain related organizational skills.

Conclusion

The livelihood strategies of rural people in the dry areas, like those in Khanasser, are dynamic. People find new ways of augmenting their income such as through off-farm employment, sheep fattening, and new crops with perceived higher benefits. Farmers' acceptance of practices with long-tern environmental and economic benefits is uncertain. The challenge for researchers is to develop options that bring about tangible improvements in people's livelihoods and the environment.

Drs Aden Aw-Hassan (A.Aw-Hassan@cgiar.org), Ahmed Mazid, and Roberto La Rovere are Agricultural Economists at ICARDA.

Crop-Livestock Integration: A Sustainable, Productive Alternative to Desertification

Much of West Asia and North Africa is threatened by desertification, in large measure due to pressure from the rising number of people who must earn their livelihood from this fragile land. By working hand-in-hand with rural communities, agricultural researchers and extension specialists in the Mashreq and Maghreb countries have made progress in refining and promoting technologies and policies that might help ensure sustainable livelihoods, and enhance the productive capacity of drylands everywhere.

By Mohammed El-Mourid, Mustapha Malki, Adnan Sheita, Abdelwahed Chriyaa, Ali Nefzaoui, Kamel Shideed, Faisal Awawedah, Salah Haj Hassan and Yassine Sweidan

Desertification threatens about 75 percent of the world's total arid and semi-arid lands, including 83 percent of rangeland, 60 percent of rainfed agricultural land, and a significant percent of irrigated land. Desertification and salinization are of particular concern in West Asia and North Africa (WANA), where most of land lies in arid environments. Population growth is placing severe pressure on the resource base, which is leading to degradation. Researchers cite mechanization of agriculture, overgrazing, cutting of forests for fuelwood, soil and water pollution, and rapid urbanization as some of the contributing factors.

The WANA region is characterized by highly erratic and deficient rainfall, resulting in severe water shortages. Human pressure on land and water has led to vulnerable and fragile agroecosystems. This is aggravated by the variability of soil and farming systems. Droughts are frequent, and human activity has only worsened the impact of drought on crops, livestock, and people. As a result, the region has begun the 21st Century facing serious food and feed deficits due to the combined effects of drought and desertification.

The region has experienced a substantial increase in livestock numbers, particularly small ruminants, over the last two decades, spurred by increased demand for animal products combined with favorable price ratios between livestock products and barley, the principal livestock feed. Feed subsidies and other measures intended to mitigate the effects of feed shortages in drought years have encouraged herders to retain greater numbers of animals.

Increase in small-ruminant numbers has led to significant changes in extensive production systems. A generation ago, native rangeland vegetation provided a large proportion of the feed needs of small ruminants. Since then, however, the contribution of natural grazing as a proportion of total feed resources in many countries has declined—from around 70% in the 1950s to only 10-25% at present. Not only are rangeland resources insufficient to meet current demand, the absolute level of feed resources is in decline due to overgrazing, removal of vegetation through plowing or fuel-wood harvesting, soil erosion, and land degradation.

Inappropriate policies regarding land use and the absence of secure property rights have exacerbated the problem. In most countries in the region, the traditional local institutions governing access to grazing lands have been disrupted, resulting in a *de facto* policy of "open access," but with no corresponding regulatory mechanism to control the extent and intensity of grazing. In addition to its unfavorable environmental impacts, there are indications that the decline in rangeland productivity is contributing to poverty and out-migration.

Research has identified technologies and management strategies for developing improved crop–livestock production systems based on on-farm feed production combined with more efficient use of alternative feed sources and improvements in livestock nutrition, health, and reproduction. However, adoption of such technologies has been slow. Furthermore, changes in the global economic environment are prompting changes in economic policies in WANA. Some countries have undertaken market reform, and the subsequent changes in relative input and output supplies and prices have influenced the investment and management strategies of small-ruminant producers in low-rainfall areas.

Development of productive and sustainable livestock-based systems in the semi-arid and arid areas of WANA requires action on several fronts. So, a program of adaptive research that integrates technologies and management practices with research on policy and institutional alternatives was implemented. Entitled "Development of Integrated Crop/Livestock in the Low Rainfall Areas of West Asia and North Africa," the program entails adaptive research in the eight countries participating in the ICARDA-led Mashreq/Maghreb (M&M) Project: Algeria, Libya, Morocco, Tunisia in the Maghreb, and Iraq, Jordan, Lebanon, and Syria in the Mashreq. The program is sponsored by the International Fund for Agricultural Development, the Arab Fund for Economic and Social Development, and the International Development Research Centre, with technical support from ICARDA and a sister center, the International Food Policy Research Institute.

The program has developed and tested several alternative technologies to combat desertification and mitigate drought, among them, cactus, fodder shrubs, and feed blocks.

Cactus Production

Cactus (*Opuntia* spp.) is well adapted to harsh, dry environment. Farmers and herders in three Maghreb countries, Tunisia, Algeria and Morocco, have long relied on the plant as a source of feed, fencing material, fruit, and fuel. It can also control erosion and even reverse rangeland desertification, especially when water-harvesting techniques are employed. Planted along furrow contours or along terraces, cactus, with its long, strong root system, can prevent runoff and stabilize slopes. The Project has tried various combinations of cactus and complimentary technology, including cement basins to collect scarce water, and cut palm fronds to stop wind erosion and sand movement. Cactus has also been used in an alley cropping system. The land is protected and farmers can grow a cash crop between rows in good years.

The Mashreq/Maghreb Project (1996–2002) has helped transfer cactus technology to the other five participating countries. Jordan, for example, has started a national project to promote spineless cactus production, Syria initiated cactus research and extension activities in 1999, and Libyan farmers began planting cactus on a large scale after visiting plantations in Tunisia.

In Tunisia, under rainfed (150-400mm/year) conditions and with no fertilizer application, spineless cactus yielded 20-100 tonnes of pads annually. As a feed it is nutritionally unbalanced, but it is a cheap source of energy, and sheep fed with large amounts to cactus for long periods are able to survive without water. When mixed with cereal straw, cactus can maintain a small ruminant herd until water and better feed become available.

Avoiding wind erosion of sandy soils by increasing plant cover (cactus and shrubs) in desert areas (Gafsa, Tunisia, 150-200 mm rainfall/year).

Fodder shrubs

Fodder shrubs, *Atriplex* spp. and *Acacia* spp., are useful in many ways: 1) to reduce grazing pressure on degraded areas; 2) as a standing fodder crop to buffer seasonal fluctuations (dry periods) that occur in arid areas; 3) as a protein supplement for livestock in poor native rangelands or low quality roughage; 4) as a forage source on arid and salt-affected regions; 5) as a source of fuel for low-income farmers; 6) as a means of soil erosion control; and 7) as an emergency feed during drought years.

The shrubs can be planted alone or in rows, with forage crops or barley between rows. Thousands of hectares have been planted to atriplex and acacia throughout the Mashreq and Maghreb, in combination with water harvesting techniques. Dry matter production varies with species and planting density. A field of *Atriplex nummularia* planted at 1000 plants/ha in Morocco produced after three years 1250 kg of dry matter/ha, equivalent to 625 forage units (UF) and 200 kg of crude protein/ha, in addition to the herbaceous production under the shrubs.

For example, an ewe of 50 kg can consume 1.5 kg DM/day. One hectare of atriplex planted at 625 plants/ha with 2 kg DM/shrub will allow 833 grazing days, which is equivalent to 2.3 ewes/ha/year, or 28 ewes/ha for one month.

Shrubs can be planted in rows and alley cropped with barley, oats, and medics. The shrubs increase total dry matter and feed units/ha, they break the wind, protect the soil, and create a microclimate that increases crop productivity.

Shrubs can be hand-fed to animals or grazed. They are high in nitrogen (especially atriplex), but low in energy, and complement two other dryland feed sources, cactus and straw. Shrub feed can replace soybean meal, decreasing feed cost, and will actually increase an animal's intake of straw.

Fodder shrubs, in combination with cactus and straw, can meet livestock feed requirements and reduce grazing pressure on rangeland, and prevent desertification. WANA is endowed with a rich genetic diversity of fodder shrub species. They are an invaluable resource in the fight to protect and rehabilitate fragile environments, but many of these native plants are endangered due to over-exploitation.

Feed blocks

Shortage of forage is one of the main limiting factors affecting small ruminant productivity in the semi-arid areas of WANA. It results in increased pressure on rangeland and to rapid deterioration of plant cover in many places. The situation is made worse by frequent droughts, which widen the gap between feed supply and the nutrient requirements of small ruminants.

The high cost of conventional concentrates—barley grain, bran, etc.—limits their use, especially by small farmers, who need cheaper alternative supplements. Crop residues and agro-industrial by-products are abundant in some places, are an obvious choice for cheap feed that can keep small-ruminants productive and relieve pressure on rangeland.

In Iraq, manufacture of pressed feed blocks made from mixtures of crop residues and agro-industrial by-products has developed into a thriving business. Various mixtures of date, tomato and beet pulp, brewer's grain, wheat and rice bran, olive cake, molasses, poultry waste, and other by-products have been used to supplement poor quality roughage and native rangeland. The blocks are considered a "catalyst supplement," allowing herders to give their animals a fractionated, synchronized, and balanced diet of energy, nitrogen, minerals, and vitamins.

The value of feed blocks lies in their low cost, their feed value, and their ability to make good use of high moisture agro-industrial by-products.

Feed blocks have been used for a long time, but the Mashreq/Maghreb Project can claim credit for reviving interest in feed block technology as an option for sheep owners in the vast semi-arid areas of WANA.

Feed blocks are easy to make, handle, and transport. They require only simple equipment and can be made on the farm. Different formulae can be followed, using varying amounts of urea and binder, and a wide range of agro-industrial by-products. In Iraq, for example, date pulp, rice bran and poultry waste are the main ingredients. In Tunisia, tomato pulp and olive cake are used. In Jordan, olive cake and brewery grains are used. In Morocco, molasses is a central ingredient.

A feed block manufacturing facility in Iraq.

Sheep in the semi-arid part of WANA feed solely on cereal stubble during summer, which coincides with the mating season. This results in lower flock productivity. In many areas, animals are fed on poor quality pasture and roughage, and in most cases their maintenance requirements are not met. Research in WANA has shown that in such situations, feed blocks can contribute to considerable improvement in ewes' weight gain, conception, lambing, and twinning rates.

In many WANA countries, sheep are hand-fed whole barley and stored straw in winter (November through January) because grazing and green roughage are in short supply. The introduction of high-energy feed blocks as a strategic supplement has resulted in significant replacement of barley grain and minimized the use of roughage and concentrates.

In Iraq, feed blocks reduced the use of conventional concentrate feeds (barley grains, commercial concentrates, etc.) by more than 50%, reducing imports considerably, especially in dry years. In Tunisia, one tonne of feed blocks costs about US$95, compared to US$200 for a tonne of barley.

Feed block technology has spread throughout the countries involved in the M&M Project. In Iraq, in particular, much research effort is going into improving and adapting the technology to the semi-arid conditions of the country. Jordan, Tunisia, and Morocco have developed community feed block units. Now, countries not involved in the Project are showing interest, including Egypt, Eritrea, Saudi Arabia, Sudan, and Turkey.

Need for enabling environment to foster the adoption of new technologies

The Mashreq/Maghreb Project was designed around the premise that a combination of appropriate technologies, policy incentives and institutional changes are required to achieve increased productivity, while maintaining the natural resource base in the low-rainfall areas of WANA. The challenge is to integrate biophysical and socioeconomic information into a coherent analytical framework for identifying the best intervention options. The Project undertook the following research activities as an integral part of technology development:

Policy research
Policy research focused on national agricultural policies, vis-à-vis liberalization, removal of subsides, and pricing. A "community model" was designed as a tool for assessing potential impact of policy reforms and evaluating new technologies and institutional options. The tool is a bio-economic model that represents the behavior of farmers, herders, and households in low-rainfall environments. It indicates the probable way in which different members of a community will respond to introduction of a new technology, resource management strategy, or policy or institutional reform. The model simulates the effects of these combinations on productivity (efficiency), incomes and income distribution (equity), and the sustainability of the natural resource base (environment).

Property rights research
Many institutional reforms have been promoted and passed in the region to support agricultural development. Each country has a different vision regarding the nature and extent of institutional reform, which include full privatization, partial privatization, and agrarian reform. There continues to be a perception, however, that existing property rights systems constrain agricultural development and discourage farmers from investing in their land and taking up new technologies. The Project's research explored whether these concerns are justified by evaluating the effects of existing land rights on long-term land improvements, and the linkages between land tenure systems, investment and land productivity, to test the hypothesis that security of tenure affects investment decisions. Land improvements include any long-term investments made by farmers to enhance farm productivity (e.g., de-stoning, tree planting, and well digging).

In rangelands, existing property rights systems (governing access and use) are failing to provide the right balance between individual and social interests in the control and management of common pastures. Ongoing research is evaluating institutional options for rangeland management, by looking at the legal and institutional environment under which they developed and the factors that contribute to their success or failure, and to assess the likely welfare effects of different options on sub-groups within the community.
This empirical information on the impact of land tenure and range management options on land users' investments and land productivity should enable policy-makers to improve the institutional environment under which rural producers make their decisions.

Community approach and parternships
The adaptive research program has shifted to testing and evaluating combinations (or packages) of associated technologies and to working at the community level, involving the local private and cooperative sector, as well as farm households.

The community approach facilitates the integration of research on policy, property rights, and the institutional and socioeconomic environment, so that issues are addressed from a technical, socioeconomic, cultural, institutional, and policy perspective.

The Project focused its efforts in two selected communities within each country. To ensure that results would be comparable and that selected communities would represent the target beneficiaries of the Project, common criteria for community selection were set.

The strategy followed in the second phase of the Mashreq/Maghreb Project, was based on a participatory approach, where every stakeholders had a role to play.

The process of community selection varied from one country to another. Generally, a target region was selected based on the overall objectives of the project and the results in phase one. Selection of communities involved several visits and meetings with farmers and community members, community leaders, and local formal and informal institutions in the target area.

Much effort was devoted to characterizing the selected communities, and identifying key constraints and potential problems, as a basis for developing community action plans. Characterization of the communities was based on data collected from rapid rural appraisals, household surveys, secondary information, and informal discussions with community members.
Characterization of communities has involved mapping of resources and other descriptors. Community participatory mapping, in which community members draw their territory and resources, allows the community to express their perceptions of their environment and land use.
The project involves a wide range of partnership among national agricultural research institutes and universities, nongovernmental organizations, the private sector, extension services, farmers and other end-users, policy-makers, international research centers, and donors.

What can be concluded?

The technologies (cactus, fodder shrubs, feed blocks), mechanisms, methodologies, and processes developed and tested within the Mashreq/Maghreb project helped empower communities, by helping them better face the challenges of living in low-rainfall areas: low productivity, land degradation, drought, desertification, high risk, and uncertainty. They can now hope to achieve sustainable livelihoods through investment in agriculture. The research conducted as part of the Mashreq/Maghreb Project in particular, and the research conducted by ICARDA in general, will help communities hold back the desert in arid environments of Central and West Asia and North Africa.■

Dr Mohammed El-Mourid (secretariat.icarda@email.ati.tu) is Coordinator of ICARDA's North Africa Regional Program and (M&M) Project Regional Coordinator based in Tunis, Tunisia; Mustapha Malki, Adnan Sbeita, Abdelwahed Chriyaa, Ali Nefzaoui, Kamel Shideed, Faisal Awawedah, Salah Haj Hassan, and Yassine Sweidan are M&M National Coordinators for Algeria, Libya, Morocco, Tunisia, Lebanon, Iraq, Jordan, Lebanon, Syria, respectively.

More Gain From Less Rain: ICARDA's Strategy to Improve Lentil for Resource-Poor Farmers in Dry Areas

In cereal-based farming systems in dry areas, lentils, like other food legumes, make an important contribution to human and livestock nutrition, to crop diversification, and sustainable agricultural production, by adding nitrogen to the soil and breaking cereal monoculture. Although lentils are adapted well to dry areas, drought poses a serious challenge to lentil farmers, particularly in the context of global warming and climate change.

Effects of intermittent drought on lentil in Nepal in 2001.

By A. Sarker, R.K. Neupane, B. Sakr, F. El Ashkar, A. Lutfi and W. Erskine

Lentil is among the most important cool-season food legumes in South Asia, West Asia, and North Africa. But in major lentil-growing areas, water is scarce and is expected to become scarcer. The key to success for the crop is greater water-use efficiency. The emphasis in lentil breeding programs must be on higher productivity in water-limited environments, so that lentil can continue to earn profit for farmers, and, thus, retain its place in rainfed cropping systems.

Research at ICARDA has shown that total seasonal rainfall accounts for 80% of the variance in mean seed yield in lentil in a typical Mediterranean climate. Severity, timing and duration of drought, however, vary from year to year, which means that cultivars successful in a particular year might fail in the next. Making matters worse, drought seldom occurs in isolation, but rather interacts with other stresses, particularly high temperature. Such interactions add to the complexity of breeding for drought resistance.

Despite these impediments, scientists at national and international research institutions remain committed to meeting the challenge. First, researchers tried to understand the mechanism of drought tolerance. They found that drought resistance can be achieved through various mechanisms: escape, dehydration avoidance, and dehydration tolerance. Escape is a particularly important strategy. It requires matching the crops development with the period of soil moisture availability to minimize the impact of drought stress. Early flowering and maturity with early and rapid biomass development are the important components of drought escape.

Terminal drought in Southeast Anatolia, in Turkey, in 1999/2000.

Progress has been made by national agricultural research systems and ICARDA in developing early-maturing genotypes with good yield. Promising genotypes are added to the Center's International Drought Tolerant Nursery (IDTN) and shared with national scientists. Breeding shorter-duration cultivars also mean that lentil can fit into more intensive cropping systems. Breeders also strive to develop genotypes that have a greater "phenological plasticity"—lines that can produce a reasonable yield under drought conditions, but continue to grow and produce more yield if

Early-maturing lentil helps escape drought.

moisture is abundant in the crop's reproductive stage.

In their search for drought-tolerant lentil, scientists have identified genotypes that have dehydration avoidance and tolerance traits and considerable variation in seedling stem length, taproot length, and lateral root number, traits directly related to yield performance. One line, ILL 8072, for example, stood up very well under severe water stress conditions, and is being used in breeding at ICARDA and elsewhere.

Research strategy

A key strategy employed by ICARDA involves selection of genetic material in target environments. ICARDA has a relatively drier testing site at Breda, in Syria, with annual average rainfall of 263 mm. In 1998/99, the site received just 195 mm, and under this severe condition, breeders were able to identify many promising lentil lines, some yielding up to 0.75 t/ha.

Since no single character — morphological, physiological or biochemical – can impart drought resistance, breeders follow a strategy called pyramiding. Beneficial traits are added to the plants, as if one on top of the other, each contributing a bit to drought tolerance, depending on the prevailing growth conditions. The same strategy is followed in breeding for disease resistance. The so-called horizontal resistance is achieved by moving different genes carrying resistance to individual physiological disease races into one cultivar. ICARDA's lentil breeding program works to combine useful traits, such as early seedling establishment, early growth vigor and canopy development, leaf area maintenance, and early flowering and maturity, all of which contribute to escape, dehydration avoidance and tolerance.

The researchers continue to search for sources of resistance among cultivated and wild species. They have identified wild accessions with high levels of drought tolerance, but these have so far been of limited value because of their meager biomass.

Above: Idlib-3 — ILL 6994
Left: Lentil crop at Breda, a dry site in Syria, 1998/99.

Marking success

The ICARDA lentil program has enjoyed notable success in developing drought-tolerant cultivars: Australia has released Cumra (ILL 590) and has identified ILL 7200 for future release; Syria has released Idlib-3 (ILL 6994); and several lines are in the pre-release stage, including ILL 7723 in Nepal, Masoor-93 in Pakistan, Bakria (ILL 4605) in Morocco, Sinai 1(selection from ILL 4605) in Egypt, and Dhamar 1 (ILL 4605) in Yemen. Many national programs are testing promising lines under farm conditions. For example, by widening the genetic base of lentil in South Asia, the national programs in the region have been able to develop early and extra-early genotypes to fit in different cropping system niches. ICARDA continues to supply promising material to national programs, which in turn select and adapt the material to local conditions. Through cooperation and sound science, the effects of drought can be reduced, for the good of farm families and national food security.

Dr A. Sarker (A.Sarker@cgiar.org) is Lentil Breeder at ICARDA; Dr R.K. Neupane is Agronomist at the National Agricultural Research Centre, Nepal; Dr B. Sakr is Grain Legume Breeder at the Institut National de la Recherche Agronomique, Morocco; Dr F. El Ashkar is Lentil Breeder, GCSAR, Douma, Syria; Dr A Lutf, is Legume Breeder, Dhamar, Yemen; and Dr W. Erskine, is Assistant Director General for Research, ICARDA.

Strategies for Overcoming Drought Stress in Chickpea

Chickpea* (Cicer arietinum *L.*) *is the third most important pulse crop in the world, and first in West Asia and North Africa (WANA). It is mainly grown in spring, taking advantage of conserved soil moisture. Because of large variations in seasonal rainfall, the crop suffers occasionally from drought. Although chickpea is known for its better drought tolerance than most other cool-season food legumes, drought does reduce yields, and can even lead to total crop failure. In 1999/2000, for example, the severe drought in WANA caused up to 75% yield losses in some spring-sown chickpea areas.

R.S. Malhotra and M.C. Saxena

What is drought?

Drought is recurring condition of abnormally dry weather leading to moisture stress for plants. Severity depends on a number of factors, including degree of moisture deficiency, its duration, and spatial spread. It can be aggravated by mismanagement of land and water resources.

Agronomic considerations

Selecting appropriate crop varieties, plant density and row spacing to reduce moisture loss by evaporation and transpiration, adjusting planting time to make better use of available water, and adopting supplemental irrigation are the agronomic practices that could help in managing drought.

Where water is available, irrigation is the main means of combating drought. Research at ICARDA's Tel Hadya station in Syria (342 mm of average annual rainfall) has shown that 50 mm of supplemental irrigation can increase the yield of spring-sown chickpea by 40%. It can be applied to save the crop in case of unexpected drought, or as a planned practice to supplement the expected total seasonal rainfall in low-rainfall areas.

Crop cultivars differ in their response to a given environment, and this difference can be of help for growers. For example, in Central and West Asia and North Africa (CWANA), and the Caucasus, a transient heat wave that normally occurs around flowering, and the failure of spring rain resulting in terminal drought stress, can cause serious yield losses due to poor seed set. Damage can be reduced by sowing a variety that can better withstand heat and drought or by adjusting planting date to avoid heat and drought damage. Sowing in winter, instead of traditional spring sowing, permits the crop to escape heat and drought. But this can be done only by using varieties specially developed for winter, i.e., having cold tolerance and resistance to blight disease. Trials over a number of years in Syria and Lebanon showed that winter sowing of such improved varieties can almost double yield compared to spring sowing. The winter-sown crop makes more efficient use of soil moisture, escapes heat and drought stress at flowering, and maturing early, it competes less with other crops for labor and machinery at harvest time. As the crop grows taller than the spring-sown crop, it is better suited to mechanical harvesting.

Most of the spring cultivars grown by farmers in WANA are susceptible to cold and ascochyta blight and cannot be used for winter sowing. Hence, ICARDA, working with national partners, has developed improved varieties for winter sowing. In 1998–2000, when drought was severe in parts of the region, farmers who adopted winter sowing of such improved varieties obtained more than a tonne of chickpea, while those who planted at the usual springtime harvested less than 300 kg/ha. National programs in 20 countries in WANA have selected and released to their farmers 40 improved varieties of chickpea from ICARDA-supplied breeding material.

Field evaluation in high-altitude areas has also identified chickpea lines that can withstand temperatures as low as –20°C, permitting late winter and early spring sowing in the high-altitude areas in Central Asia and the Caucasus and in Iran. Farmers there have recognized the benefits of early sowing and have started adopting the practice. Government agencies and non-governmental organizations in some countries are now producing improved seed and conducting demonstrations to enhance farmer awareness.

Genetic enhancement for drought tolerance

Drought tolerance refers to the ability of a variety to remain relatively more productive than others under limited water conditions. Drought tolerance/resistance is a very complex trait associated with different attributes. Plants usually adapt to drought stress through three major mechanisms, namely, escape, avoidance and resistance. Although the genetic and physiological bases of these mechanisms have not been established precisely, they have been indirectly exploited by chickpea breeders in developing drought-tolerant cultivars. But, as drought is unpredictable, regular selection of cultivars at a particular site under natural conditions is extremely difficult.

Breeding for drought tolerance

Drought tolerance research in chickpea at ICARDA has addressed various strategic options and found that productivity under drought conditions can be improved using two steps in the breeding process: (1) rejection of lines with low productivity in low-input, drought-prone marginal conditions, and (2) and selecting for high productivity in the evaluation of remaining lines in high-input, drought-prone marginal environments. This approach has been successful. For example, a popular line, Gokce (FLIP 87-8C), has shown its ability to adjust to changing environmental conditions. As there is no single trait—morphological, physiological or biochemical—which alone is responsible for drought tolerance, ICARDA follows a gene pyramiding approach to develop breeding material with high yield and drought tolerance. Bringing genes together in one line (gene pyramiding) for various complementary traits—such as early seedling establishment, early growth vigor, early flowering and maturity—that contribute to escape, dehydration avoidance, and tolerance, results in achieving relatively stable drought tolerance

Screening for drought tolerance

Different methods of screening for drought tolerance have developed and used at ICARDA.

Using a line-source sprinkler irrigation system, a continuous soil moisture gradient (ranging from none to full irrigation) is created, upon which chickpea genotypes are evaluated for seed yield. Genotypes are scored using drought response index (DRI, the ratio of yield under stress and that without stress), and genotypes with high DRI are selected. Using this technique, it was observed that early flowering is the main component of drought escape in chickpea, and that it is associated with high harvest index, the number of pods per unit area, and seed yield. Using this technique, good progress has been made in developing early maturing genotypes, without compromising on yield.

Crop species have evolved several mechanisms to maintain required water status in their tissues for normal metabolic function under limited soil moisture supply or when atmosphere is excessively desiccating. Dehydration avoidance (DA) is a mechanism that allows the plant to retain a tissue water

Screening for drought tolerance in chickpea using late spring planting in WANA to select resistant lines.

content during drought stress permitting important plant productive functions to continue. DA is influenced mainly by different root attributes, including root size, morphology, depth, length, density, hydraulic conductance, and others. Since screening for differences in root length and density is very laborious and time consuming, indirect selection through related traits is more practical. Studies of the relationships between different root, shoot and some morpho-physiological parameters have shown that a combination of traits, including earliness to flower, high harvest index and deep rooting, which are responsible for large average yields, should be used as criteria for improvement of DA. Some traits, such as stomata number and size, leaf rolling, leaf movement, and high level of reflectance, which have been reported as good indicators of DA in other crops, can also be explored in chickpea.

In environments where water deficit can occur at any stage of growth, dehydration tolerance (DT) might play a role in crop survival until soil moisture levels improve with succeeding rains. For such conditions, ICARDA has started using the box screening technique under controlled conditions to evaluate genotypes for DT. Dehydration tolerance relates to the ability of cells to continue metabolizing in times of low moisture. Wooden boxes at least 20 cm deep are filled with a 1:1 mixture of sterilized soil and sand. Seeds of different genotypes are planted in equally spaced rows and at equal depth and the soil-sand mixture is saturated with water. No more water is applied throughout the trial. Evaluation for DT is carried out when the susceptible check line shows wilting. Leaf samples from different genotypes are assessed for cell leakage using an electro-conductivity test. Lines are scored as drought tolerant or susceptible based on number of days they take to show wilting or based on the amount of solute leaching from cells.

The techniques mentioned above are useful and reliable, but they are also time-consuming, expensive, and cumbersome. ICARDA, jointly with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), has developed a simple field screening technique for handling large numbers of lines at a time. Material to be screened is planted in late spring (20 March at Tel Hadya) and is evaluated using a scale of 1 to 9 (1 = free of visible drought effects, very good early plant vigor, 100% pod setting; 9 = highly susceptible, lack of early plant vigor, no flowering, no pod setting, no yield, all plants killed). Promising lines (with ratings 1–5) are sown, with and without supplemental irrigation, in replicated trials. Lines producing high yields (more than the mean of the trial) under these late sown (drought) conditions, and those responding well to supplemental irrigation are selected. Many lines selected using this technique have been shared with ICARDA's national partners through the Center's Legume International Testing Program as part of the Chickpea International Drought Tolerance Nursery. Several have shown promise in the recipient countries.

In a search for additional sources of tolerance to drought, ICARDA researchers evaluated different accessions of annual wild *Cicer* species and observed that *C. reticulatum*, *C. judaicum*, and *C. bijugum* were more drought tolerant than others. *C. reticulatum* is easily crossed with cultivated chickpea and is being used in ICARDA's breeding program.

As drought tolerance is a complex trait, drought occurrence is unpredictable, and screening not very reliable, there is a need to exploit molecular techniques, including identification of QTLs, genes, and molecular markers for marker-assisted selection.

What the future holds

Greater attention has been paid to drought tolerance in the last few years and several evaluation techniques based on morphological, physiological, and adaptive traits have been developed. Studies on measurements of root length, root density, osmoregulation, and most of the other adaptive traits have revealed that these are time- and resource-consuming approaches. Thus, empirical yield-based screening methods will continue to dominate for drought screening unless more simple and refined techniques, such as molecular marker assisted breeding, are identified that might enhance the efficiency of classical breeding.

Dr R.S. Malhotra (R. Malhotra@cgiar.org) is Senior Chickpea Breeder and Dr M.C. Saxena (M.Saxena@cgiar.org) is Assistant Director General (At-Large) at ICARDA.

Drought Network...

Continued from page 11

- Facilitating the development of national, sub-regional, and regional project proposals to address drought priority areas
- Streamlining exchange of information on monitoring tools and data on early warning among members
- Promoting the exchange of information on mitigation practices and coping mechanisms to support the decision making process in member countries
- Strengthening and developing human and institutional capabilities at the national level
- Promoting cooperation in planning and implementing drought mitigation programs at national and regional levels
- Disseminating information among concerned organizations/institutions on pertinent drought issues, and promoting professional contacts, study tours, expert meetings, training courses
- Coordinating activities with other relevant regional and international networks.

Functions and activities

The network will:

- Convene periodic meetings for the Network Executive Committee to discuss the network work plans, evaluate programs and their implementation
- Establish and develop regional databases and directories for professionals and institutions relevant to drought monitoring, assessment, mitigation, and management
- Organize, alone or with collaborating agencies, working sessions, workshops, and seminars on specific aspects of drought and prepare thematic studies
- Review and assess current practices, plans of action, and policies followed in member countries
- Assist in developing individual national plans of action and early warning and monitoring units, and assist in the collection of data
- Promote joint collaborative activities among countries to consolidate the linkages and synergy in resources utilization for research, training, and networking
- Establish and operate a communication system on drought mitigation.

Representatives of the six sub-regions, in addition to the representatives of ICARDA, FAO and CIHEAM, will form the Executive Committee. The network will seek support from governments, funding agencies, individuals, national, regional or international organizations, development banks, and others.

"The Network participants are optimistic that the effects of drought can be reduced for the good of farm families, countries, and the entire region."

A concerted effort

Drought is an international challenge, so it makes sense that the countries in the Near East, Mediterranean, and Central Asia work to increase transborder cooperation. With its mandate to improve nutrition and income in the world's dry areas, and supported by its wealth of experience in dryland agriculture, ICARDA is well placed and fully competent for its role in NEMEDCA. The Network participants are optimistic that the effects of drought can be reduced for the good of farm families, countries, and the entire region.

Dr Theib Oweis (T.Oweis@cgiar.org) is Water Management Specialist at ICARDA.

Breeding for Improved Resistance to Drought in Durum Wheat

ICARDA's main research station and its related testing sites in the Near East are located in the heart of the Fertile Crescent. The research sites are also representative of the harsh Mediterranean dryland climate, which is characterized by extremes of temperature and moisture availability. This means that ICARDA is ideally placed to conduct breeding for drought tolerance. Together with the International Maize and Wheat Improvement Center (CIMMYT) and its national partners, ICARDA is making great strides in improving durum wheat. More improvement is promised, thanks to the use of emerging technologies and the region's age-old dryland agrobiodiversity.

By Miloudi M. Nachit

Durum (*Triticum turgidum* L. var. durum) wheat is grown mainly in Central and West Asia and North Africa (CWANA) under variable environmental conditions. These environmental variations are the main cause of yield reduction and fluctuation. In the Mediterranean drylands, abiotic stresses, such as drought, cold and heat, are the most important constraints. Biotic stresses, including diseases and insects, also take their toll. In fact, CWANA has the highest number of damaging insect biotypes and some of the most virulent diseases that cause damage to agriculture.

This combination of abiotic and biotic stresses makes plant breeding in the Mediterranean dryland areas complex and very challenging. In 1977, ICARDA initiated a dryland durum-breeding program in partnership with CIMMYT. The program's main objective is to develop genotypes and genetic stocks combining yield potential with resistance to drought and other abiotic and biotic stresses, and with improved grain quality. During the last 10 years, stress-tolerant and high-yielding durum genotypes developed at ICARDA have resulted in spectacular gains in Syria, which has seen annual production increase from less than 1 million tonnes in the 1980s to 5.4 million tonnes today.

Drought resistance breeding

Because the Mediterranean drylands are characterized by a high year-to-year variability, breeding cultivars that combine drought resistance, yielding ability, and yield stability is the objective of the ICARDA breeding strategy. In our selection approach, all early segregating populations are subjected in representative selection environments to the stresses encountered in the Mediterranean drylands. Landraces and wheat wild relatives are the main sources of drought resistance. Stress-physiology-traits tools and molecular-marker techniques are also used to efficiently select drought-resistant durum genotypes. The methodology allows identification, in the early stages, of the populations that combine drought resistance, productivity, stability, and resistance to biotic and abiotic stresses.

Selection environments

To enhance drought tolerance and adaptation and yield stability, a double gradient selection technique (DGST) was developed in the early 1980s. The DGST sites are representative of abiotic and biotic stresses in CWANA for temperature extremes varying from cold to hot, and water regimes varying from severe drought to irrigated conditions. The DGST covers five environments that are extensively used during the various phases of selection in segregating populations and testing of advanced lines. Further, the DGST also covers, at ICARDA headquarters, six environments using staggered sowing dates (early planting, rainfed, irrigated, late planting, summer planting), and sowing after the hay vetch crop harvest.

Use of genetic wheat diversity

Mediterranean durum landraces were found to possess desirable traits for resistance to drought, early growth vigor, long peduncle, and high fertile tillering capacity. Use of the landraces in the hybridization program has shown substantial progress can be achieved. Selection for drought resistance has been performed in populations from crosses between improved durum lines, landraces, and durum wild relatives. Wild relative are used to widen the genetic base of durum and improve its resistance to abiotic and biotic stresses. Genotypes generated from hybridization with *Triticum* wild relatives have been found to produce high grain yield under favorable and dry conditions. Under drought, the best crosses were those with *Triticum carthlicum, T. dicoccoides, T. monococcum, T. polonicum, T. dicoccum and Aegilops* species.

Continued on page 26

A drought-tolerant durum wheat genotype developed using a combination of conventional techniques and biotechnology tools.

Breeding Barley for Drought Resistance

In most developing countries where barley is cultivated, the crop predominates in areas where other rainfed cereals are unprofitable or not possible to grow. This is due to climatic stresses, among which drought is by far the most important. Therefore, breeding barley cultivars more resistant to drought than those currently available is one of the most important objectives of the barley-breeding program at ICARDA.

Water availability has been a dominant factor in the rise and fall of ancient civilizations. The regions surrounding the "Twin Rivers," Tigris and Euphrates, and the mighty Nile and Indus, were the birthplaces of civilization. After several millennia, water continues to be a factor of life or death for both humans and animals.

Water is becoming an increasingly scarce resource—about one-third of the human population does not have sufficient water; and given that about 70% of available water is used in agriculture, breeding for drought resistance has to be seen as one of the best ways, and possibly one of the cheapest ways, of saving water globally.

Studies show that water is used inefficiently in both irrigated and rainfed agriculture. There are two main ways of increasing water-use efficiency in agriculture. One is to convert more water into transpiration. This challenge lies in the domain of physical engineering, hydrology, and agronomy. The other is to increase the transpiration–water use ratio. This job goes to plant breeders, physiologists, and geneticists.

Barley is a good model plant to study physiological, genetic, and breeding aspects of drought resistance. In many countries the crop is of great economic importance in areas where drought and other abiotic and biotic stresses make the cultivation of other rainfed crops impossible or uneconomical.

Two contrasting approaches have been followed in breeding crops for drought tolerance. The first uses selection under optimum growing conditions, and is based on the assumption that increased yield potential will have a carry-over, or spillover, effect when the improved cultivar is grown under less favorable conditions. The second uses direct selection in the presence of drought, i.e., in the target environment, and can take two forms: selection for physiological or developmental traits (also called analytical breeding), and direct selection for grain yield (also called empirical or pragmatic breeding). Environment here is defined as the complex of climate, soil type, soil depth, soil fertility, agronomic management, etc.

In discussing with researchers the rainfall distribution and risk in her barley production, farmer Juri Aboud used stones of different sizes as visual aids. The survey results indicated that farmers preferred a stable variety over a high-yielding but unstable one.

By Salvatore Ceccarelli and Stefania Grando

The first approach has failed to produce convincing results. In fact, drought continues to affect agricultural production negatively worldwide despite spectacular increases in crop yield potential obtained through breeding under optimum conditions. An example of the absence of spillover effect is offered by wheat production in Syria, which in the period 1984-2000 (the first improved cultivar was released in 1983) increased by a staggering 50 kg/ha per year, to the point where Syria is now a wheat exporter. However, this large increase in yield potential of new cultivars was achieved under irrigated conditions and had no significant effect on yield under rainfed conditions, even though the adoption level of improved cultivars has reached almost 90%.

Breeding for drought resistance based on putative traits (traits associated with drought resistance, but easier to select for than grain yield) has been and still is very popular. Traits that have been investigated include (1) physiological/biochemical traits, such as proline content, stomatal conductance, epidermal conductance, canopy temperature, relative water content, leaf turgor, abscisic acid content, transpiration efficiency, water use efficiency, carbon isotope discrimination, and retranslocation; and (2) developmental/ morphological traits, such as leaf emergence, leaf area index, leaf waxiness, stomatal density, tiller development, flowering time, maturity rate, cell membrane stability, cell wall rheology, and root characteristics. In the case of barley, we have found that the traits more consistently associated with higher grain yield under drought include growth habit, early growth vigor, earliness, plant height under drought, long peduncle, and short grain filling duration.

While the analytical approach has been very useful in developing an understanding of which traits are associated with drought tolerance and why, it has been less useful in actually developing new cultivars with improved drought resistance under field conditions. This is because, under field conditions, drought varies in timing, intensity and duration, and therefore it is the interaction among traits that determines the overall crop response to the variable nature of drought stress, rather than the expression of any specific trait. Recently, a similar level of complexity has been revealed in analysis of drought responses at the molecular level. In addition, drought is often associated with other abiotic stresses, particularly temperature, either high or low, as well as biotic stresses, and the way in which these various stresses combine and occur.

Although breeding for drought resistance based on direct selection for grain yield in the target environment (empirical or pragmatic breeding) appears intuitively the most obvious solution, this approach faces two major problems: the precision of the yield trials conducted in dryland conditions, and the existence of several target environments, each characterized by its own specific type of drought and combination of stress.

The first problem has been largely overcome by the considerable progress that has been made recently in both experimental layout and statistical analysis. It is now possible to conduct trials outside the closely controlled conditions of the research station without losing precision.

The problem of target environments is typical of areas where the risks of crop loss and of low yield are so high as to discourage the use of external inputs. This low use, or no use, of inputs has the effect of maximizing environmental differences between different areas and between different cropping seasons within the same area. Breeders working in unfavorable environments must account for another challenge—large genotype-by-environment interaction, which makes finding a broadly adapted variety more difficult. To account for this, the ICARDA barley breeding program has used selection for specific adaptation (adaptation to a specific harsh environment) as a strategy to breed for drought resistance. Critics point out that this strategy is usually associated with a reduction in yield potential under favorable conditions. The matter must be considered in its social context, and in relation to the difference between adaptation over space versus adaptation over time. For example, Australian farmers prefer maximizing yield in favorable years, while for North African and Near Eastern farmers, yield in very poor years is more important.

Selection for specific adaptation has entailed evaluating early segregating populations (populations still showing much variability between plants) in dry sites, such as Breda and Bouider in Syria. The most important results of this choice have been the re-evaluation of the role of landraces in breeding for drought tolerance, and the discovery of the importance of the wild progenitor of cultivated barley, *Hordeum spontaneum*, as a source of resistance to extreme levels of drought. This was evident during the drought of 1987 when two lines of *Hordeum spontaneum* were the only survivors in the breeding nurseries grown at a very dry site, which received just 176 mm of rainfall.

Participating farmers discuss with researchers the performance of their barley crop in a drought-hit field.

In the early 1990s the concept of breeding for specific adaptation was incorporated into the development of germplasm for international distribution, using a decentralized breeding approach. By this we mean the development of segregating populations from targeted crosses and their distribution to each of several target regions for selection and testing.

There are some major implications of adopting decentralized breeding as a breeding approach in international breeding programs. First, national programs generate more varieties, each adapted to specific conditions, including the different types of drought characterizing each country, and, second, the superior performance of the varieties developed for low-input and less-favored lands will not depend on agronomic practices that require large amount of inputs. A breeding program based on this approach is less likely to endanger biodiversity and the environment.

Although the concept of decentralized breeding is usually well received by national programs, decentralization *per se* does not necessarily respond to the needs of resource-poor farmers in less-favored areas. If decentralization means simply a shifting of breeding work to outlying stations, and if the outlying stations are not representative of a country's harsh marginal areas, as is often the case, then nothing much is achieved. To exploit potential gains from specific adaptation to low-input conditions in general, and to drought in particular, breeding must be shifted from research stations to farmers' fields.

Although decentralization and farmer participation are unrelated concepts, decentralization to farmers' fields almost inevitably leads to the participation of farmers in the selection process. In the case of the ICARDA barley program, the idea of farmer participation in formal breeding programs arose originally from a desire to conduct decentralized selection to exploit genotype × environment interactions and a desire to capitalize on farmers' knowledge about the crop, its specific uses, and its specific adaptation. In other words, decentralized, participatory barley breeding represents an evolution of a breeding strategy to improve drought resistance.

Progress has been slow, as expected, given the large genotype × year interactions, and given the fact that drought resistant lines can only display their true value when a drought actually occurs. The yield advantage of some of the highest yielding lines at a dry site in 1999 (200 mm rainfall) amounted to 14% over the landrace and 38% over Rihane-03, which yielded nearly 20% less than the local landrace in dry years and in dry sites.

Continued on page 30

Drought-resistant durum...
Continued from page 23

Use of stress physiology

The ICARDA durum program has found that earliness, fertile tillering, spike fertility, peduncle length, and early plant vigor are associated with higher grain yield under drought conditions. Fertile tillering is, however, by far the most potent predictor of durum wheat grain yield under moisture-stress conditions. Other physiological measurements were made. Comparison between the Near East landraces and the ICARDA-improved durum genotypes showed that significant genetic gain in grain yield is associated with physiological traits such as photosynthesis and osmotic adjustment.

Use of molecular markers

The program is using molecular markers to identify drought resistance traits difficult to select for, using conventional field or laboratory methods. Drought resistance in durum was found to be associated with some molecular markers and morpho-physiological traits. The quantitative trait loci (QTL) analysis was conducted on mapping Jennah Khetifa/Cham 1 (JKC) and Omrabi5/*T. dicoccoides*// Omrabi5 (MDM) populations. Markers linked to drought resistance and grain quality are being identified. In JKC and MDM, QTLs for grain quality were determined — for gluten strength, protein content, yellow pigment, alpha-lipoxygenase, flour extraction, and test weight. As for drought resistance, the carbon isotope discrimination (CID), which we have shown to correlate positively with grain yield and its components, was found to be located in the JKC & MDM on different chromosomes (4Bs and 3Bl).

The combination of different research tools in the improvement of durum cultivars has generated promising genetic material for the Mediterranean drylands. Research is ongoing to combine genes for drought resistance in durum for further enhancement of yield and yield stability.

Dr Miloudi M. Nachit (M.Nachit@cgiar.org) is CIMMYT/ ICARDA Durum Wheat Breeder, based at ICARDA.

Two Vetches Hold Promise in Drought-Prone Areas

The major limiting factor to livestock production in dry areas is inadequate feed supply. A severe shortage in feed resources occurs when growing seasons are constrained by low rainfall. Prolonged periods of drought with intermittent and inadequate rainfall affect the land and livelihoods of millions of resource-poor farmers throughout Central and West Asia and North Africa. Vetch, a versatile forage legume can help. It is good for the soil, good for livestock, and ultimately good for the farmers who must eke a living from drought-prone areas.

Sheep grazing improved vetch (*Vicia sativa *ssp.* amphicarpa*) on marginal lands in Syria.

In the past two decades, ICARDA has recognized and begun to capitalize on the great value of forage legumes, such as vetch (*Vicia* spp.), as an essential component of sustainable dryland farming systems. They are a good potential source of feed for the rapidly growing livestock populations in Central and West Asia and North Africa (CWANA). They withstand drought, and need less water to produce high amounts of herbage, grain and straw. And because of their ability to fix nitrogen from the air (performed by Rhizobium in root nodules) they are a "fertilizer factory on the farm."

By Ali M. Abd El-Moneim and Zhibiao Nan

ICARDA is investigating two vetches, narbon vetch (*Vicia narbonensis* L) and underground vetch (*Vicia sativa* ssp. *amphicarpa*), for their usefulness in areas that receive less than 300 mm rainfall. Narbon vetch has high yield potential and drought and cold tolerance. It is a good source of protein. Its seeds contain 28% protein, yielding around 365 kg protein per hectare. Its straw contains 9% protein.

Some cultivars and promising lines developed at ICARDA have shown high seedling vigor, with rapid winter growth and negligible cold damage. At Breda in Syria in 1998/1999, one of the driest growing seasons on record (total precipitation 198 mm, 58% of long-term mean annual rainfall), improved lines of narbon vetch yielded more than 1.8 tonnes per hectare grain and 4.5 tonnes per hectare straw, much higher than other legumes.

Results obtained from Gansu province in China confirmed narbon vetch's adaptation to harsh conditions. In Cyprus, after five years of testing breeding lines, the national program released IFLVN # 567 as a variety for cultivation in dry areas.

These results demonstrate that narbon vetch is a dependable feed legume where other legumes are not successful. The seeds contain protein with an amino acid composition nearly equivalent to that of soybean. New improved varieties are low in gamma–glutamyle–S ethyle Cystein (GEC), a sulfur compound that reduces grain palatability and leads to reduced feed intake in monogastric livestock.

This crop can substantially increase feed production and farm income in rotation with barley, particularly in areas where barley monoculture is becoming more common due to pressure on land availability, and which in turn is leading to low barley yield.

Narbon vetch at Breda in 1998/1999 (rainfall 198 mm).

Narbon vetch, successfully grown in Gansu province, China.

Underground vetch showing above-ground and underground pods.

Underground vetch

The so-called underground vetch produces more than half of its pods underground, leaving a good seed bank for self-regeneration in the next season. It is tolerant to drought and has a good persistency even under heavy grazing, thus, providing particularly valuable forage under marginal conditions. Available landraces, however, have relatively low herbage yield. Breeders have been successful in obtaining increased herbage yield by crossing underground vetch with promising lines of common vetch. This vetch holds promise for rehabilitating marginal lands and in ley farming systems, and in rotation with barley in areas too dry for production of other vetches and medics (*Medicago* spp.).

Dr Ali M. Abd El-Moneim (A. El-Moneim@cgiar.org) is Senior Forage Legume Breeder at ICARDA; Dr Zhibiao Nan is a Professor of Pasture Agronomy and Director, Gansu Grassland Ecological Research Institute, Chinese Academy of Agricultural Sciences.

Collecting and Conserving Genetic Resources to Meet Future Needs

Water scarcity is one of the 21st Century's major challenges. In the rainfed farming systems of semi-arid regions, drought stress is common and unpredictable. According to climate-change models, annual fluctuations in rainfall are likely to increase in most of Central and West Asia and North Africa (CWANA) in the coming decades. To counter this serious threat to agricultural production, ICARDA and the national agricultural research systems in CWANA focus much of their effort on breeding for improved drought tolerance and increased water-use efficiency. To be successful, they need a ready supply of genetic diversity from which to select needed traits.

ICARDA's mandate crops—barley, wheat, lentil, faba bean, chickpea, and forage legumes—were domesticated in CWANA some 8,000–10,000 years ago. Over the millennia, they have developed, through selection by farmers, various adaptive mechanisms for drought stress tolerance. Crop wild relatives represent an even richer source of genes for stress tolerance and adaptation, because they have been around much longer, and have survived periods of very harsh climate, especially in the Pleistocene Era.

Landraces in farmers' fields and populations of crop wild relatives in low-rainfall and drought-affected sites are natural reservoirs of genes for drought tolerance, but they are now increasingly threatened by genetic erosion. The principal cause is changes in traditional agro-ecosystems, such as replacement of genetically diverse landraces with uniform modern varieties, cultivation of rangeland, and overgrazing leading to the loss or degradation of habitat for crop wild relative populations. To save the rich genetic diversity and make it available to researchers and breeders, plant collectors carry out collection missions, in which landrace and wild relative populations are sampled and conserved in genebanks. The centers of Consultative Group on International Agricultural Research (CGIAR) have some of the world's most comprehensive collections of plant germplasm, which they hold in trust under the auspices of the Food and Agriculture Organization of the United Nations.

Dryland agrobiodiversity in West Asia gave the world such important crops as wheat and barley, a number of pulses and fruit trees. This agrobiodiversity continues to sustain the livelihood of local communities and provide useful genes for plant breeding programs worldwide.

The world's genetic heritage held safely in trust

Genetic resources collections held at ICARDA total 129,000 accessions, 20% of the germplasm accessions held in trust by the CGIAR centers, of which ICARDA is one. Two-thirds of ICARDA's genebank accessions originated from countries of Central and West Asia, North Africa and Mediterranean Europe, where a harsh and stressful climate of pronounced seasonality with cold and rainy winters and long hot and dry summers is typical. Within- and among-season weather fluctuations are also unpredictable.

The geographical origin of ICARDA's genebank collections is well documented. The latitude and longitude of collection site are available for 60,000 accessions,

By Jan Valkoun

including 6,000 accessions of crop wild relative, 20,000 accessions of wild forage, pasture and rangeland species and 34,000 crop landrace accessions, which were collected from 22,000 different sites.

Probably the most valuable part of ICARDA's genebank holdings were collected on the more than 160 missions that the Center has conducted in collaboration with its national program partners. These missions covered 32 countries, targeted mostly at low-rainfall and drought affected areas in CWANA.

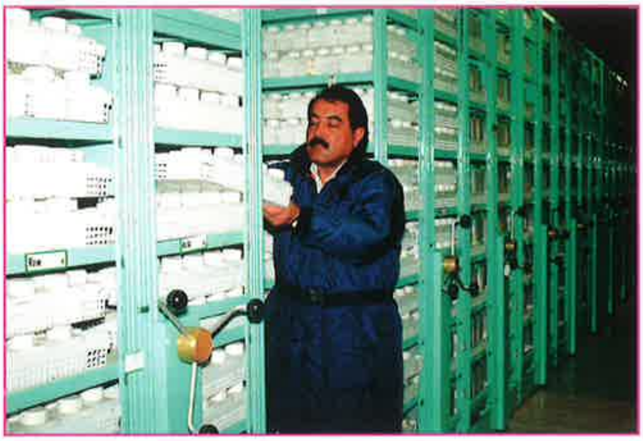
In total, ICARDA's collection effort has so far yielded 26,000 new genebank accessions, of which more than 23,000 were collected in 21 CWANA countries. A number of wild relative and landrace accessions were sampled from very dry sites of less than 300 mm annual rainfall (Tables 1 and 2).

Drought-hardy wheat relative, part of collection

Several species of goatgrass such as *Aegilops bicornis, Aegilops crassa, Aegilops kotschyi, Aegilops searsii, Aegilops vavilovii* and *Aegilops tauschii*, prefer dry environments. At least half of these wild relatives of wheat were found in dry sites (Table 1). *Ae. tauschii* is of particular interest, since gene transfer from this drought-adapted species to bread wheat is relatively easy. Others are also of interest. A number of drought-adapted accessions were found in wild progenitors of wheat, barley and lentil, i.e., *Triticum dicoccoides, Hordeum spontaneum* and *Lens orientalis*, respectively, which cross easily with the cultivated species. Their chromosomes are similar and any 'wild' genes can be transferred through chromosome recombination in meiosis. In addition to wild species, many landrace accessions have been collected from rainfed sites with annual rainfall below 300 mm (Table 2). The significant proportion of landraces (28%) originating from dry sites is a reflection of ICARDA's focus on drought in its collection strategy.

Table 1. Crop wild relatives collected by ICARDA in dry sites.

Gene pool	Wild relatives	Accessions collected by ICARDA in: <300 mm sites	Accessions collected by ICARDA in: all sites with precipitation data available	Percentage of dry sites (less than 300 mm sites)
Wheat	*Aegilops bicornis*	11	14	79
	Aegilops crassa	24	48	50
	Aegilops kotschyi	37	47	79
	Aegilops searsii	26	46	57
	Aegilops tauschii	56	93	60
	Aegilops vavilovii	54	74	73
	Triticum dicocoides	76	532	14
	Triticum urartu	19	84	23
	Other species	154	1287	12
	Total	**457**	**2225**	**21**
Barley	*Hordeum spontaneum*	113	357	32
Lentil	*Lens orientalis*	19	121	16
	Lens odemensis	5	36	14
	Total	**24**	**157**	**15**



A view of the ICARDA genebank.

Table 2. Crop landraces collected by ICARDA in dry sites.

Crop	Accessions collected by ICARDA in: <300 mm sites	Accessions collected by ICARDA in: all sites with precipitation data available	Percentage of dry sites (<300 mm sites)
Durum wheat	82	334	25
Bread wheat	104	374	28
Barley	300	532	56
Lentil	63	504	13
Chickpea	61	351	17
Faba bean	31	209	15
Total	**641**	**2304**	**28**

Making the most of modern information technologies

Recent advances in information technology, such as geographic information systems (GIS) and remote sensing technology, have increased map resolutions to scales sufficient for detailed climatic characterization of the geographical distribution of wild relatives of wheat, barley, lentil and chickpea, and forage, pasture and rangeland species in CWANA. The feasibility of such an approach was documented in a recent ICARDA study, in which a total of 67 climatic and four soil variables were generated for 391 collection sites in Syria, from which ICARDA genebank accessions were collected and geographic coordinates were known. These accessions represented 183 wild *Triticum* and 558 *Aegilops* populations belonging to 4 and 16 species, respectively. The data were subsequently subjected to different statistical analyses, and wheat wild relatives adapted to specific stresses, including drought, were identified. The use of geographic positioning systems (GPS) equipment on collection missions has substantially increased the accuracy in determining collection site location, which is a prerequisite for the GIS analyses.

Large genetic resources collections, such as ICARDA's, contain genotypes that tolerate stress in many different ways. Stress tolerance demands both perception of stress by the plant and induction of the mechanisms that permit the plant to withstand and recover from stress. Advances in molecular biology open new opportunities for understanding the physiological, developmental, and genetic means by which these mechanisms are controlled.

The high genetic diversity for the components of abiotic stress response, existing in large germplasm collections, must be properly evaluated and documented in order to be useful in meeting the challenges posed by abiotic stresses, drought in particular. In stressed environments, individual stress effect usually cannot be separated from the multiple-stress response. So researchers attempt to characterize germplasm in controlled conditions using morpho-physiological criteria, which can reveal new insights into different components of abiotic stress response. Moreover, advances in molecular biology are providing new means of understanding the physiological and genetic mechanisms involved in plant response to different stresses. The field is also providing tools for molecular screening and genetic engineering applications in crop improvement for increased abiotic stress tolerance. A thorough evaluation and exploration of genetic diversity existing in the crop wild relative and landrace collections held at ICARDA might be a strategic first step in germplasm development to counter the negative impact of climate change on rainfed farming systems.

Genebank collections only a part of the story

Ex situ gene bank collections represent only fractions of the rich genetic diversity that has accumulated for millennia in the natural populations and farmers' fields and orchards. Therefore, the *ex situ* effort has to be complemented by conserving agrobiodiversity *in situ*, in the original habitat, in partnership with those who manage and utilize it—farmers, herders and their communities. Several projects in the CWANA region are testing the *in situ* or on-farm approach to biodiversity conservation. The Dryland Agrobiodiversity Project, funded by the Global Environment Facility and the United Nations Development Programme, is working to conserve biodiversity through promotion of its profitable utilization by farm families and communities. The comprehensive project, which operates in Jordan, Lebanon, the Palestinian Authority and Syria, is coordinated by ICARDA in collaboration with the International Plant Genetic Resources Institute and the Arab Center for the Studies of Arid Zones and Dry Lands. It is focused on the globally important indigenous genepool of cereals and pulses, forage and pasture legume wild species, and several fruit tree genera. The main task of the project is to identify and test, in participation with local communities and other stakeholders, sustainable options for *in situ* conservation of the target germplasm. The ultimate aim is improved livelihoods through sustainable utilization of the indigenous agrobiodiversity. Communities are helped to profit from the plant heritage passed down from generations of their ancestors, and in the process secure it for generations to come. For unless people see a value in agrobiodiversity, it will be lost to neglect, replaced by introduced species or pushed to extinction by habitat change.

The two approaches to conservation of genetic resources—*in situ*, including on-farm conservation through utilization, and *ex situ*—are complementary. Both are essential for maintaining the rich genetic diversity on CWANA and providing breeders, molecular biologists, and other scientists with drought-tolerance genes to meet current and future needs. ■

Dr Jan Valkoun (J.Valkoun@cgiar.org) is Head of the Genetic Resources Unit at ICARDA.

Drought Resistance in Barley...

Continued from page 25

Year 2000 saw the first real demonstration that the combination of 1) direct selection in the target environment, 2) the use of landraces and *H. spontaneum*, and 3) plant selections made by farmers, could increase the crop's resistance to extreme drought. In that year, total rainfall in most areas of Syria was below average, and crop yields were severely affected. In some areas, rainfall was so low that the crop failed to germinate, in many others the crop failed to produce grain.

In trials in farmers' fields in some very dry locations in Syria (Tel Brack, Hassakeh province with 87 mm rainfall; Jurn El-Aswad and Bylounan, Raqqa province, 121 and 87 mm, respectively; and Bari Sharky, Hama Province, 130 mm), the only entries able to produce grain and/or biomass were all derived from crosses with those two lines of *H. spontaneum* identified in 1987 at Bouider. Grain yield was between 300 and 500 kg/ha and biomass yield was between 500 and 3000 kg/ha. These yields appear very low, but to the farmers in these areas any yield is very important because it reduces the economic impact of drought.

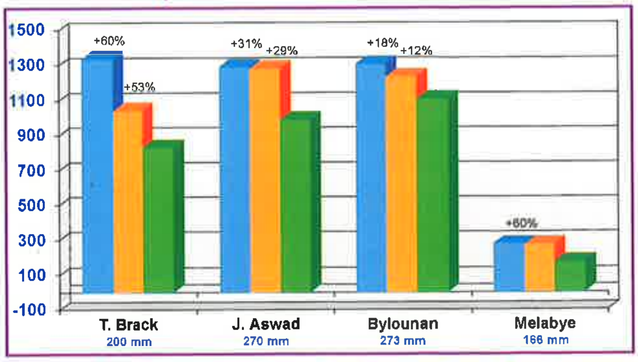


Figure 1. Grain yield of barley lines selected by farmers in four villages in the dry areas of Syria compared with the local landrace Arabi Aswad (in green).

More recently, in a range of conditions, including rainfall between 160 mm and 270 mm, much higher yield gains were observed over the local landrace, Arabi Aswad, which continues to predominate in the dry areas of Syria (Fig. 1). It appears as if successive cycles of participatory plant breeding are enhancing drought resistance much more rapidly than in the 15 years of on-station selection.

Data obtained during 2002 confirmed that decentralized, participatory plant breeding can be very powerful in adapting the crop to a wide range of specific environments, even within a limited geographical area. □

Dr Salvatore Ceccarelli (S.Ceccarelli@cgiar.org) and Dr Stefania Grando (S.Grando@cgiar.org) are barley breeders at ICARDA.

Promoting *in situ* Conservation of Agrobiodiversity in West Asia

Conservation of dryland agrobiodiversity is receiving increasing attention in response to emerging global concerns over biodiversity loss, desertification, and global warming. Dryland agrobiodiversity in West Asia sustains the livelihood of local communities and provides useful genes for plant breeding programs worldwide. ICARDA has collected with national agricultural research system partners (NARS) more than 129,000 accessions of its mandate crop plants, landraces, and wild relatives of important crop species. These are stored (*ex situ*) in the Center's genebank. Conservation on site (*in situ*), in farmers' fields or protected areas, has been promoted recently as a complementary method to conserve a larger genetic base, while benefiting from natural selection and the knowledge of local communities.

By Ahmed Amri, Jan Valkoun and Ali Shehadeh

The GEF/UNDP dryland agrobiodiversity project

A five-year project entitled "Conservation and Sustainable Use of Dryland Agrobiodiversity" was launched in 1999 to promote *in situ* conservation and sustainable use of dryland agrobiodiversity in Jordan, Lebanon, the Palestinian Authority and Syria. The project is funded by the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP), and is coordinated regionally by ICARDA. ICARDA also facilitates networking and provides technical backstopping and training, requested by national components, in cooperation with the International Plant Genetic Resources Institute (IPGRI) and the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD). The project focuses on conservation of landraces and wild relatives of barley, wheat, lentil, allium, feed legumes (*Lathyrus, Medicago, Trifolium* and *Vicia*), and fruit trees (olive, fig, almond, pistachio, plum, peach, pear, apple). A holistic approach based on the involvement of major stakeholders, principally farmers and herders, and on the coverage of major ecosystems and farming systems is followed. The main outputs of the project relate to: (1) assessment and monitoring of agrobiodiversity and generating knowledge about major factors contributing to its degradation; (2) demonstration of low-cost technologies and ways to increase the productivity and marketability of products making use of agrobiodiversity; (3) drafting of appropriate policy and legislation reforms; (4) enhancing capacity building; (5) increasing public awareness; (6) investigation of alternative sources of income; and (7) impact assessment and contribution to the development of scientific basis for *in situ* conservation.

The project activities are implemented at the national level by national research institutes: National Center for Agricultural Research and Technology Transfer (NCARTT) in Jordan, Lebanese Agricultural Research Institute (LARI) in Lebanon, and General Commission for Scientific Agricultural Research (GCSAR) in Syria and the Ministry of Agriculture and UNDP/PAPP in the Palestinian Authority.

A nursery in Lattakia for landraces and wild relatives of fruit and forest tree species.

Major achievements

Output 1: Status of agrobiodiversity and major factors of its degradation

Socioeconomic surveys found that all farmers are using only landraces of barley, lentils, figs, and olives. Most farmers still use wheat landraces, except in the West Bank, where half of the farmers use improved varieties. More than half of the farmers still use landraces of almond, apricot, and plum. The quality and adaptation advantages of landraces are well known to farmers. The area planted to these landraces is decreasing due to the rapid spread of apple, cherry, and olive plantations. Ecogeographic surveys conducted in 55 monitoring areas showed that the agrobiodiversity in natural habitats is affected mainly by overgrazing, encroachment of agricultural land, and by expansion of quarries.

Diversity of fruit trees in an orchard in Ajloun, Jordan.

Output 2: Demonstration of low cost technologies and income opportunities

The performance of landraces of cereals and food and feed legumes increased by more than 50% on some farms following the cleaning and treatment of seeds against seed-borne diseases and use of herbicides, which shows the need to develop a community-based informal seed-increase system. The technologies demonstrated to landrace fruit-tree growers included water harvesting, pruning, integrated pest management, use of foliar fertilizer, and others. To promote rangeland rehabilitation, the project demonstrated techniques for reseeding with native species, application of phosphorus, controlled grazing, water harvesting, plantation of shrubs, and production of feed blocks, designed to reduce pressure on local species during critical times.

The project selected 24 *in situ* conservation sites and helped private and public nurseries collect cuttings of landraces and seeds of wild fruit trees to be used for afforestation.

The project also focused on training local communities, mainly women, in production of jams, compotes, syrups, and dried fruits. The project introduced the practice of making jam from zizyphus and wild pyrus fruits, and helped set up agrobiodiversity shops in Ajloun (Jordan) and Al-Haffeh (in Syria), both historical sites, to allow the sale of local products.

Output 3: Reforms of national biodiversity policies and legislation

The project developed a framework that includes steps to follow in the development of national biodiversity policies and legislation. The framework is shared with many other projects and with biodiversity national experts from 14 Arab countries who participated in the "First Arab Workshop on the Implications of International Agreements on the Development of National Policies and Legislation Related to Biodiversity Conservation," organized by the project at the Arab League headquarters in Cairo. Draft policies have been produced by Jordan, the Palestinian Authority and Syria, which are being discussed with government officials, biodiversity committees, and local communities. The project is seeking the expertise of the Food and Agriculture Organization of the United Nations to help in drafting national policies on access and exchange of genetic resources.

Output 4: Capacity building

Some 34 graduate and undergraduate students were supported in their studies and national and regional training courses were conducted for project team members, the staff of national executing institutions, extension staff, and forestry departments. The training covered use of DNA molecular tools and geographic information systems and remote sensing in assessing agrobiodiversity and genetic diversity; ecogeographic/botanic conservation; taxonomy and identification of target species; participatory breeding; *in situ* conservation and genebank management; rangeland and livestock management; water harvesting; food processing; and other topics.

An inexpensive water-harvesting technique using site stones at Wahadna, Jordan.

Output 5: Increasing public awareness

Increasing the awareness of the general public and collaborating farmers is an important task of the project. This was undertaken through workshops and meeting with local communities, media interviews (TV, radio, newspapers, newsletters, and websites), production of posters and documentary films, use of rural theater, and organization of agrobiodiversity fairs. The project is collaborating with Ministries of Education to introduce biodiversity conservation in education systems. Teachers were instructed on agrobiodiversity, and extra-curricula activities were organized aimed at engaging children and parents. These activities included creation of environment clubs, promotion of school gardens, painting contests, visits to project sites, documentation of parents' knowledge of local plants and their uses.

Her Royal Highness Princess Basma Bint Talal of Jordan inaugurated the agrobiodiversity fair in Ajloun, in Jordan.

Output 6: Investigation of alternative sources of income

The project is investigating alternative income sources for local communities, the custodians of agrobiodiversity. Training and technical support were provided on honey production and bee keeping, improvement of dairy products, cultivation of medicinal and herbal plants, and creation of private and community nurseries. Contacts with private agencies and government institutions were initiated to promote ecotourism.

Output 7: Project impact assessment

The preliminary indicators of project impact are very encouraging. The project helped in the setting up of agrobiodiversity programs in research institutions in Jordan, Lebanon and Syria, and in the creation of agrobiodiversity units in the Ministry of Agriculture, Palestinian Authority, and in the Forestry Department in Jordan. There has been a shift toward the use of wild relatives of fruit trees in afforestation efforts. In Syria, 500,000 seedlings of target landrace species were planted in 2003, compared to 30,000 in 1999. Awareness is increasing at all levels regarding the need to conserve agrobiodiversity. This has facilitated collaboration with tourism and education ministries and with other projects and nongovernmental organizations. Sites rich in agrobiodiversity have been identified and designated so by governments, after approval by local communities. Many accessions of target species have been collected and placed in genebanks. Protocols for ecogeographic/botanic survey database management were set and a policy framework was developed and shared.

Planting wild species of fruit trees during the creation of a school garden

Lessons learned

Research and extension efforts should contribute to the promotion of conservation and sustainable use of dryland agrobiodiversity. Further success will be achieved if the role of local communities is fully recognized, evidenced by their full participation, empowerment, and sharing in resulting benefits. The project has highlighted activities and actions that will contribute to the ultimate goal of improving the livelihood of local communities while conserving agrobiodiversity, but increased national and international support is needed to conserve endangered agrobiodiversity. Lessons should be drawn from the failed expansion of alternative crops promoted at the expense of rich local agrobiodiversity.■

Dr Ahmed Amri (A.Amri@cgiar.org) is GEF/UNDP Agrobiodiversity Project Coordinator, Dr Jan Valkoun is Head of the Genetic Resources Unit, and Dr Ali Shehadeh is a Researh Assistant at ICARDA.

Harmonization of Seed Regulations— An Insurance Policy Against Drought

Work to ensure a reliable seed supply should start at home, but when countries work together to meet their common need for quality seed, much more can be achieved. Imagine new varieties moving freely across borders, and shipments of high quality seed of adapted varieties arriving just in time to help a country recover from drought. Harmonization of national seed sectors has already begun. Through hard work and sustained commitment on the part of national governments, the dream of a borderless regional seed sector should soon turn into reality.

By Zewdie Bishaw and Tony van Gastel

Drought: A threat to food security

Disaster comes in many forms: drought, flood, hurricane, war, civil disturbance, to name a few. Among the natural disasters, drought is common in a large proportion of Central and West Asia and North Africa (CWANA), the regional geographic mandate area of ICARDA.

Drought affects agricultural production, the human population, and the environment. It can cause a mild drop in agricultural production, or wipe out the productive capacity of whole regions, and cause long-term alterations to ecosystems. Drought is also one of the main causes for seed insecurity, through destabilization of rural populations, and disruption of agricultural production, leading to depletion of seed stocks. In severe cases, drought can lead to the loss of valuable genetic diversity, the building blocks for rehabilitation and restoration of agricultural systems.

Seed: Key to restoration of agriculture

Seed is the key to maintaining on-farm crop diversity, food security, and transferring technology (i.e., increased production potential in the form of improved crop varieties) to farmers. Seed is also central to any emergency intervention to restore food production. For example, the success of agricultural rehabilitation following drought depends mainly on farmers' access to seed of adapted crop varieties. Thus, it is very important that seed-supply strategies be in place, not only to ensure availability under normal conditions, but also to ensure supply during and after emergencies.

Strategies should be considered at the household, community, national and regional levels. Each level requires a different approach, but they must all be closely linked, integrated and complementary to ensure food production in all circumstances. Often, rehabilitation efforts focus on emergency food supply while

Cham-1, a durum wheat variety developed in Syria but widely grown in West Asia, North Africa and beyond, is an example of how the benefits of agricultural research and development can cross borders, given sufficient cooperation between countries.

neglecting the more strategic issue of seed.

Regional cooperation in seed production and marketing can help ensure seed security and contribute substantially to agricultural rehabilitation after serious drought. Success depends on the existence of strong national seed systems and farmer-based community seed banks and strategic-area reserves of adapted local crop varieties.

Harmonized seed regulations

Harmonization of seed policies, laws, and regulations should help to quickly restore a sound base for agricultural production in the event of drought.

If policies are the same, then "senior policy makers in different countries have a common understanding of how they wish to see the seed industry develop in their countries," says Dr Salah Abdel Wanis, former Under-Secretary for Seed in Egypt.

"But similar laws and seed regulations also mean similar procedures and similar seed production standards, which will simplify and speed up the emergency response to make available seed of adapted crop varieties to farming communities in the drought-stricken areas," says Dr Wanis, whose views are shared by representatives of agricultural research development.

"Variety evaluation and release procedures should be similar, or, even better organized on a regional basis," says Dr William Erskine, ICARDA's Assistant Director General for Research.

There would be no need for further evaluation of a variety and no concerns of mal-adaptation. This would simplify greatly the movement of a variety from one country to another, which means that rehabilitation could be very fast. For this vision to become reality, national seed certification programs would need to be standardized, or at least modeled on similar lines. The best strategy might entail establishment of a regional seed certification scheme, such as that of the Organization for Economic Cooperation and Development. Seeds certified under such a scheme can easily move from one member country to another, without hindrance.

"If only standards [for genetic and seed quality] would be uniform across the region, acceptance of seed from other countries would not raise an eyebrow," says Dr Abdul Mohsin Omar Sayed, Director General of the General Organization for Seed Multiplication, Syria.

While the benefits of free-movement of seed are obvious, so too are the dangers posed by the introduction of diseased seed, pests, or weeds. However, science-based pest risk assessment, based on guidelines set down by the International Plant Protection Convention, would give quarantine regulators a reasonable level of confidence.

"We must not forget quarantine regulations, but uniform regulations across countries would make the need for seed health testing minimal," says Dr Ahmed El-Ahmed, in charge of ICARDA's Seed Health Laboratory.

ICARDA's efforts in ensuring seed security

Because ICARDA works in fragile environments where drought is common, the Center recognizes the importance of strong links between national crop improvement programs in the region. To help foster these links, ICARDA's Germplasm Program brings scientists together for annual planning meetings and scientific workshops.

"These annual planning meetings are not only important to discuss specific country programs and agree on priority research issues," says Dr Tom Blake, Director of the Germplasm Program, "but also to ensure that programs have a regional focus."

The Center-run international nursery program coordinates region-wide evaluation of breeding lines and promising varieties. It also runs traveling workshops to evaluate performance of new adapted germplasm across the region. This helps identify varieties with wider or specific adaptation, reducing the need for repeated evaluations of promising lines in individual countries.

At the same time, ICARDA's Seed Unit maintains ties with public and private seed organizations throughout the region.

"The West Asia and North Africa Seed Network is basically an information network, but our ultimate aim is to initiate the process of harmonization of seed rules and seed laws," says Dr Bahattin Bozkurt, Deputy Director General for Agricultural Development and Production, Ministry of Agriculture, Turkey.

Networking for regional integration

Established 10 years ago, the WANA Seed Network has 19 member-countries and is linked strongly to 11 regional and international organizations dealing with agriculture and/or seed sector development. The Network promotes cooperation, facilitates exchange of information, and provides a forum for sharing experience, expertise, and resources. Exploiting synergy among national programs is a major objective. It is a catalyst to seed-sector harmonization intended to lead to a strong and dynamic seed industry in the region.

The Network realizes that harmonization is not easy. Changing policies, laws and regulations will require a lot of consultation between experts, policy makers, and legislators.

As a first step, information on different national seed policies was collected, summarized, published, and circulated among member-countries and beyond. The Network is now preparing a draft uniform seed policy for consideration by member-countries. Similarly, national seed certification programs in each member country have been analyzed and a draft regional certification scheme has been developed. Some countries have already taken action. The Egyptian member representatives, for instance, have requested their country's Ministry of Agriculture to endorse the scheme. Variety release must also be harmonized, so the Network will carry out a comprehensive study of similarities and differences of the various mechanisms, including variety evaluation, registration, and release procedures in the member-countries. The study will also cover policy and regulatory, technical and administrative

Participants in the workshop on "Review of National Seed Systems and Regulations in Central and West Asia," held in Karaj, Iran, on 2-3 November 2002.

issues affecting commercialization of varieties.

Among the valuable information compiled is a catalog of all field and seed standards. It covers important cereals, legumes, oilseeds, industrial crops, forages, and selected vegetable crops in member-countries, and should simplify the task of developing common standards. A catalog of all varieties released and commercialized in member-countries has also been produced and is regularly updated.

To ensure that all laboratories carry-out tests in a similar fashion and that results of tests are comparable between member-countries, a proficiency testing system is implemented among the seed testing stations in the region. The test has been carried out for cereals, legumes, and forage crops.

A summary of rules and regulations on seed trade and regional data on seed import and export are available, as is a directory of seed producers, importers and exporters, and national organizations dealing with policy and regulatory issues on agricultural research, varieties, and seeds.

ICARDA also commissioned a study of the seed sector in selected countries. The review covered crop research and seed supply, policy and regulatory framework in variety release and registration, seed quality control and certification, and seed/grain trade and quarantine regulations. The result includes lists of crop varieties (suitable for drought-prone areas), seed producers and available facilities, agencies responsible for seed quality control, seed/grain trade and quarantine, and nongovernmental organizations involved in agricultural development and emergency seed supply.

The Karaj workshop: A first step

Collection of information is just the start. Harmonization process is the goal.

To this end, in November 2002 ICARDA and its national agricultural research system partners held a workshop on "Review of National Seed Systems and Regulations in Central and West Asia," in Karaj, Iran. At the workshop, senior managers and policy makers from Afghanistan, Azerbaijan, Iran, Iraq, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkmenistan, Turkey, and Uzbekistan explored opportunities for harmonization of seed policies and regulations, and endorsed the harmonization initiative. Stakeholders at the national and regional level will meet again to come up with a final agreement that meets the region's needs.

Looking ahead

Food and seed security are linked, and seed security programs must be in place to cope with man-made and natural disasters, of which drought is probably the most threatening for CWANA. Seed security must be addressed from a broad perspective—household, community, national and regional levels—that goes beyond emergency seed relief. All farmers should have access, at all times, to seed of adapted crop varieties.

Seed security can be achieved more easily when countries have open-door policies and encourage harmonization of seed policies, laws and regulations that result in the free movement of new varieties and seed across national boundaries.■

Dr Zewdie Bishaw (Z.Bishaw@cgiar.org) is Seed System Specialist and Dr Tony van Gastel is Head of the Seed Unit at ICARDA.

Expert Systems: Useful Tools for Enhancing Agricultural Research and Production

An expert system is a computer program that simulates a human expert in solving a problem in a narrow domain area. Computer expert systems have been used in agriculture since the early 1980s. Several systems have been developed in the United States and Europe for plant-disorder diagnosis, to assess production practices, technologies, and other aspects of farming. In Egypt, the Central Laboratory for Agricultural Expert Systems (CLAES) of the Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation, has the mandate to identify and develop expert systems and train researchers, extension specialists, and growers in their use, including maintenance and updating. CLAES has developed and deployed several plant and animal agricultural expert systems.

By Samir El-Sebae Ahmed, Ahmed Rafae and Khalid Shaalan

Expert systems differ from traditional computer software applications in that they deal with a symbolic knowledge base and not a database or mathematical models, but they can also be integrated with traditional software to form a complete system. They safeguard and continue to make good use of the expertise of highly qualified specialists, even after the specialists retire or leave an institute's service. An expert system can also integrate the knowledge base of different specialties, such as irrigation, nutrition, plant pathology, and entomology in one package. The expert system's advice takes into consideration the specific data of a certain plantation, whereas traditional extension documents leave part of the reasoning up to the grower, as it is impossible to include all possible situations. Therefore, expert systems can play a valuable role in transferring agricultural research results to farmers' fields efficiently, through the existing extension systems, as the number of extension and growers is large relative to the number of researchers who can respond to the needs of extensionists and growers.

Annually, since 1997, a two-week regional training course on "Utilization of Expert Systems in Agricultural Research and Production" has been conducted jointly by the International Center for Agricultural Research in the Dry Areas (ICARDA) and CLAES in Cairo, Egypt (Table 1). The course introduces expert systems technology to senior and mid-level management from the countries of Central and West Asia and North Africa. The course covers the basic components of an expert system and how they differ from other types of software programs, such as databases and simulation modeling. The course also covers briefly the expert system development life cycle, namely: knowledge acquisition, knowledge analysis and modeling, requirement specifications, design, implementation, verification and validation, evaluation, maintenance, and training. An expert system development tool is also introduced and participants develop experimental prototype expert systems in their specialties.

NEPER strategic component main menu

The Follow-up Study

To determine the impact of this new technology on the former participants and their national agricultural programs, a comprehensive questionnaire was prepared and forwarded in early 2002 to all the former training course participants. Twenty-two completed questionnaires were received and analyzed. Fifteen former participants were invited to a follow-up training workshop held in

Table 1. Number and origin of national scientists who participated in the ICARDA/CLAES joint training course on "Utilization of Expert Systems in Agricultural Research and Production," 1997-2001.

Region	No. of participants	Country
West Asia	20	Iraq, Iran, Jordan, Lebanon, Syria, Turkey
Nile Valley and Red Sea	13	Egypt, Eritrea, Ethiopia, Sudan
Arabian Peninsula	10	Oman, Qatar, Saudi Arabia, UAE, Yemen
North Africa	5	Algeria, Libya, Morocco, Tunisia
Central Asia	3	Armenia, Kazakhstan, Tajikistan
Total	**51**	

First follow-up workshop in Egypt to evaluate the impact of expert systems in agricultural research and production. Former trainees in the ICARDA/CLAES courses participated in the workshop.

October 2002 at CLAES headquarters in Cairo.

The workshop was held to 1) assess the impact of the annual course, 2) identify the problems faced by former participants in developing expert systems in their countries, 3) update the former participants on the latest methodologies and tools for developing expert systems, and 4) help ICARDA make correct decisions on continuation, content, duration and further improvement in the course. Thirteen invitees took part from Egypt, Ethiopia, Jordan, Qatar, Lebanon, Morocco, Sudan, Syria, Turkey, and Yemen.

The workshop participants recommended that the course be continued at CLAES. It was also recommended that more emphasis be placed on issues related to the design and implementation of expert systems for specific agricultural operations. A set of expert system building tools was developed at CLAES for user-friendly utilization by agricultural researchers and others. These tools will be used to develop expert systems in future courses.

Workshop outcomes

Course content and material

- More information on design and implementation issues related to expert systems, such as user-interfaces, control strategy, etc., needs to be included in the course.
- The expert system building tools should be upgraded for smooth, user-friendly utilization by agricultural researchers and other users.
- Practical training should address wider issues of interest to national programs.
- Course materials and the expert system building tool and its user manual should be available on the Internet for easy downloading and up-dating.

Who should attend the course?

- Research scientists and extension/technology transfer specialists should continue to attend the course, but they must have a good grasp of the English language and computers.
- Computer specialists should be invited to the course to encourage the creation of teams of expert systems specialists at the national program level.

Course duration and location

- Most of the participants said the present two-week course is too short. It was suggested that the course be extended by a week to allow more practical work on design and implementation issues. If cost prevents this, then the two-week course should be intensified so that more time per-day is allocated for practical training.
- The course should continue to be conducted at CLAES headquarters in Cairo and/or at another country in the region.

Introducing new courses

- Courses oriented toward design and implementation issues related to expert systems and building tools should be organized for computer specialists with programming skills.
- Courses to 'train-the-trainers' in expert systems should be organized at CLAES headquarters, with follow-up, on-the-job training at the country, sub-regional, and regional level.
- A highly specialized course was recommended for national programs progressing well in building their own expert systems.

Communication between CLAES and former participants

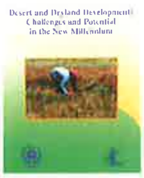
- To enhance links between former participants, CLAES and ICARDA, it was recommended that a website be built that includes contact information of the former participants, as well as course material, tools, and solutions to common problems. This website was developed during the workshop: http://www.claes.sci.eg/meetings/icardaws
- It was suggested that participants who develop their own expert systems might benefit from feedback from CLAES. It was requested that any scientist who develops an expert system send it to CLAES for further validation and evaluation.

Conclusion

Expert systems were recognized by most of the participants as a useful tool for transferring agricultural knowledge between researchers, extension officers and growers, as well as for assisting decision makers in solving agricultural problems. National cooperators appreciate the joint efforts of ICARDA and CLAES in developing and organizing this course.■

Dr Samir El-Sebae Ahmed (S.Ahmed@cgiar.org) is Head of the Human Resources Development Unit at ICARDA, Dr Ahmed Rafae is Director of the Central Laboratory for Agricultural Expert Systems (CLAES), Cairo, Egypt, and Dr Khalid Shaalan is Senior Scientist, CLAES.

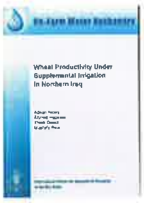
Recent Publications



Desert and Dryland Development: Challenges and Potential in the New Millennium. Proceedings of the Sixth International Conference on the Development of Dry Lands, 22-27 Aug 1999, Cairo, Egypt. 2002. Ryan, J. (ed.). 655 pp. ISBN: 92-9127-130-0. US$ 80.

Meeting the Challenge of Yellow Rust in Cereal Crops. Proceedings of the Regional Conference on Yellow Rust in the Central and West Asia and North Africa Region, 8-14 May 2001, Karaj, Iran. 2002. Johnson, R.; Yahyaoui, A.; Wellings, C.; Saidi, A.; Ketata, H. (eds.). 280 pp. US$ 35.

On-farm Soil and Water Management in Central Asia. Proceedings of an International Workshop, 17-19 May 1999, Tashkent, Uzbekistan. 2002. Karajeh, F.; Ryan, J.; Studer, C. (eds.). 164 pp. US$ 20.



Wheat Productivity Under Supplemental Irrigation in Northern Iraq. On-Farm Water Husbandry Research Report Series, No. 2. 2002. Adary, A.; Hachum, A.; Oweis, T.; Pala, M. 38 pp. US$ 10.

An Agroecological Exploration of the Arabian Peninsula. 2002. De Pauw, E. 77 pp. US$ 10.

Developing and Harmonising Biosafety Regulations for Countries in West Asia and North Africa. 2001. Proceedings of a Workshop. FAO/GTZ/USDA/SAEC/ AGRERI/ ICARDA/USDA-FAS/AFESD. 11-13 Sept 2000, Aleppo, Syria. Baum, M.; de Kathen, A.; Ryan, J. (eds.). 163 pp. US$ 20.00.

Field Guide: Insect Pests of Wheat and Barley in North Africa, West and Central Asia 2001. Parker, B.L.; El-Bouhssini, M.; Skinner, M. 120 pp. US$ 15.

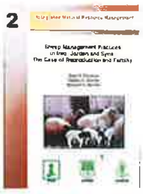
Can Pastoral Institutions Perform Without Access Options?. 2001. T. Ngaido. ICARDA Social Science Paper No. 9. 25 pp. US$ 10.

Collective Action, Propert Rights, and Devolution of Rangeland Management: Selected Examples from Africa and Asia. 2001. T. Ngaido and M. Kirk. ICARDA Social Science Paper No. 10. 34 pp. US$ 10.

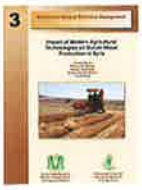
Supplemental Irrigation Potential for Wheat in the Central Anatolian Plateau of Turkey. 2001. Oweis, T.; Salkini, A.; Zhang, H.; Ilbeyi, A.; Ustun, H.; Dernek, Z.; Erdem, G. 37 pp. US$ 10.

Water Harvesting : Indigenous Knowledge for the Future of the Drier Environments. 2001. Oweis, T.; Prinz, D.; Hachum, A. 36 pp. (Available in English or Arabic) US$ 10.

Supplemental Irrigation: A Highly Efficient Water-use Practice. 1997. Oweis, T. 16 pp. US$ 10.



Sheep Management Practices in Iraq, Jordan and Syria: the Case of Reproduction and Fertility. Integrated Natural Resource Management Research Report Series No. 2. 2003. Thomson, E.F.; Martini, M.A.; Tutwiler, R.N. 43 pp. ISBN: 92-9127-133-5. US$ 10.



Impact of Modern Agricultural Technologies on Durum Wheat Production in Syria. Integrated Natural Resource Management Research Report Series No. 3. 2003. Mazid, A; Tutwiler, R.N.; Al-Ahmed H.; Martini, M.A.; Maya, F. 34 pp. ISBN: 92-9127-135-1. US$ 10.

Prepayment in US dollars is required with all orders. Checks written in the name of "ICARDA" must be drawn on a US branch of any bank or on a branch of any US-based bank. UNESCO coupons and international money orders are accepted, and should also be made payable to ICARDA. The sale of publications listed here is subject to availability of stock. Send checks to: Head Communication, Documentation and Information Services, ICARDA, P.O. Box 5466, Aleppo, SYRIA

Phone: (963-21) 2213433, 2213477, 2225012, 2225112

Fax: (963-21) 2213490, 2225105

E-mail: s.varma@cgiar.org

Donors to ICARDA, 2002

Listed in descending order of contribution

1. USAID (United States Agency for International Development)*
2. WORLD BANK*
3. EUROPEAN COMMISSION
4. UNITED KINGDOM
5. AFESD (Arab Fund for Economic and Social Development)
6. IFAD (International Fund for Agricultural Development)
7. ITALY*
8. THE NETHERLANDS*
9. GERMANY*
10. NORWAY*
11. JAPAN*
12. EGYPT*
13. SYRIA*
14. DENMARK*
15. SWEDEN*
16. ASIAN DEVELOPMENT BANK
17. CANADA*
18. AUSTRALIA*
19. UNDP (United Nations Development Programme)
20. IRAN*
21. IDRC (International Development Research Centre)
22. USDA (United States Department of Agriculture)
23. FRANCE*
24. BELGIUM*
25. UNEP (United Nations Environment Programme)
26. FAO (Food and Agriculture Organization of the United Nations)
27. OPEC (Organization of Petroleum Exporting Countries)
28. ETHIOPIA
29. INDIA*
30. TURKEY
31. SWITZERLAND
32. SOUTH AFRICA

* Donors that provided core funds