Collection and conservation of genetic resources for dryland farming systems

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Abstract

Crop wild relatives and landraces in the Central and West Asia and North Africa (CWANA) region of origin and diversity of wheat, barley, lentil, chickpea, faba bean and forage legumes are a rich reservoir of genes for drought-stress tolerance adaptation to dryland environments. However, they are under rapid genetic erosion and have to be conserved both *ex situ* in genebanks and *in situ* in original habitat to meet the present and future needs. Out of the total of 131,000 accessions held in ICARDA's genebank collections, two-thirds originate from the CWANA region. In more than 160 collection missions to 32 countries the Center collected 26,000 new genebank accessions. For 57,000 geo-referenced accessions 65 climatic variables were generated using GIS. Accessions sampled from drylands, i.e. hyper-arid, arid and semi-arid zones prevail with 2%, 12% and 41%, respectively. In a complementary effort, the GEF/UNDP Dryland Agrobiodiversity Project is testing in Jordan, Lebanon, the Palestinian Authority and Syria the *in situ* or on-farm biodiversity conservation through promotion of its profitable utilization by farm families and communities. Both approaches are essential for maintaining the rich genetic diversity of CWANA and providing breeders, molecular biologists and other scientists with sources of drought-tolerance genes.

Media summary

Genetic resources from CWANA region of crop diversity are conserved both *ex situ* and *in situ* to provide drought-tolerance genes for dryland farming systems.

Key words

Drought, genetic resources, *ex situ* conservation, *in situ* conservation, ICARDA

Introduction

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 8000–10,000 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.

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 world's genetic heritage held safely in trust

Genetic resources collections held at ICARDA total 131,000 accessions, 20% of the germplasm accessions held in trust by the centers of the Consultative Group on International Agricultural Research, of which ICARDA is a member. 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, 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.

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. Recently, many GIS generated data were added to ICARDA genetic resources database. A total of 65 climatic variables and information on UNESCO agro-climatic zones and soil type are available for 57,000 accessions collected from more than 16,000 sites. Accessions sampled from drylands, i.e. hyper-arid, arid and semi-arid zones prevail with 2%, 12% and 41%, respectively.

Large genetic resources collections, such as ICARDA's, contain genotypes that tolerate stress in many different ways. Stress tolerance demands both perception of stress 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, and drought in particular. In stressed environments, individual stress effects 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 in the extensive semi-arid and arid drylands of developing countries in CWANA.

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 Studies of the Arid Zones and Dry Lands, Syria. It is focused on globally important cereals and pulses (indigenous genepool), 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 the margins of fields and roadways, or to extinction by habitat change.

Conclusion

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 of CWANA and providing breeders, molecular biologists, and other scientists with drought-tolerance genes to meet current and future needs.

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

Gene pool	Wild relatives	Accessions collected by ICARDA in		Percentage of dry sites (less than 300 mm
		<300 mm	all sites with	

		sites	precipitation data available	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 dicoccoides	58	188	31
	Triticum urartu	21	76	28
	Other species	154	1287	12
	Total	441	1873	24
Barley	*Hordeum spontaneum*	113	357	32
Lentil	*Lens orientalis*	19	121	16
	Lens odemensis	5	36	14
	Total	24	157	15

Table 2. Crop landraces collected by ICARDA in dry sites

Crop	Accessions collected by ICARDA in		Percentage of dry sites (< 300 mm sites)
	<300 mm sites	all sites with precipitation data available	
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