ARC-ICARDA Collaborative Program

Highlights of Reports and Achievements

2010-2014

وزارة الزراعة واستصلاح الاراضى
Ministry of Agriculture and Land Reclamation
ARC
مركز البحوث الزراعية
Agricultural Research Center

ICARDA
Science for Better Livelihoods in Dry Areas

Table of Contents

List of Tables

List of Figures

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Highlights of Reports and Achievements, 2010-2014

1. Introduction

Egypt has been an active collaborator of the Consultative Group on International Agricultural Research (CGIAR) since 1978 with the signing of a cooperation agreement with the Ministry of Agriculture and Land Reclamation. ICARDA's partnership with Egypt and specifically the Agricultural Research Centre (ARC) has over the years strengthened research capacities in areas that include crop improvement, cropping system management, improved water productivity and irrigation efficiency, salinity management, crop-livestock production system, biotechnology and human and institutional capacity development.

More recently, a Memorandum of Understanding between ARC and ICARDA was signed in 2009 concerning a ten-year joint program for wheat improvement in irrigated areas in Egypt to serve similar agro-ecologies. The objective of this program was to develop wheat germplasm with the attributes suitable for irrigated agriculture (including high yield potential, heat tolerance, good grain quality and resistance to diseases and insect pests), and to make the germplasm freely available, in the form of international nurseries to national wheat breeding programs in the areas of concern to ICARDA, particularly Central and West Asia and North Africa (CWANA) region.

In order to further boost Egypt-ICARDA collaboration in agricultural improvement and sustainability, Egypt decided to utilize half of its annual financial contribution to the CGIAR (amounting to 250,000 US$) to support specially collaborative projects between ARC and ICARDA. Since 2008, ten projects have been supported, covering different thematic areas such as wheat improvement, legumes improvement, barley seed enterprises, water and land productivity, and livestock biodiversity.

2. Highlights of Achievements:

The 2010-2014 achievements of the different programs under ARC-ICARDA collaboration are summarized below:

2.1 Wheat Improvement Program

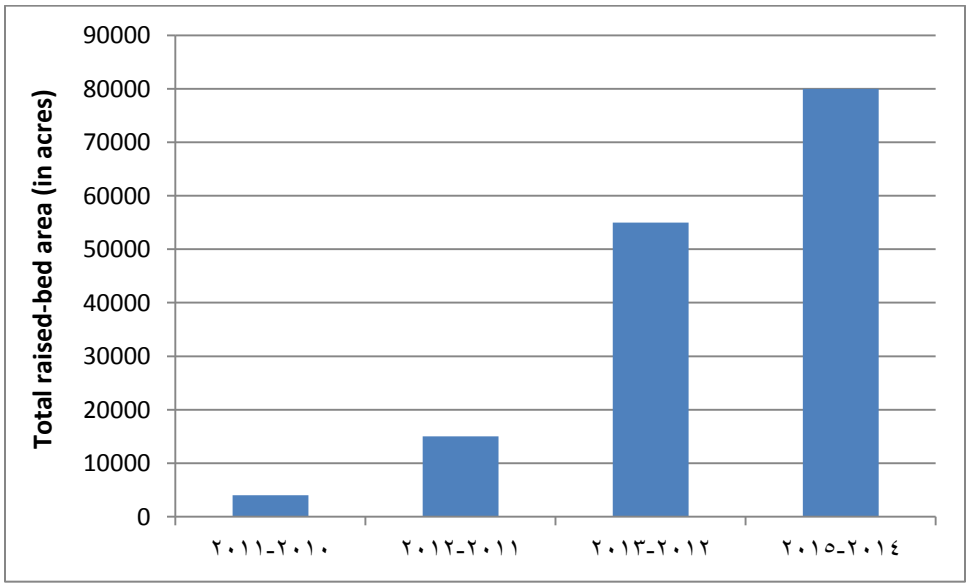
Background:

Egypt is a major wheat producer in CWANA region and wheat is considered to be a strategic commodity for food security in the country. In Egypt, wheat is cultivated on about 1.3 million ha with an annual production of about 7.5 million tons. However, this is not sufficient to meet the domestic demand. As such, Egypt imports between 7-9 million tons of wheat every year. Also, with current population growth, the country's wheat demand is expected to increase. Despite this, Egypt's national

policy is aiming to achieve 75 percent self-sufficiency in wheat production. This can be achieved through genetic improvement in productivity, since horizontal expansion for land has rather limited scope. At the same time, wheat productivity is already very high (6.7 tons/ha) in Egypt. Hence, to go vertical is indeed a gigantic task for which ARC-ICARDA collaboration is considered very strategic and highly relevant.

Considering this, ICARDA and ARC agreed to collaborate in developing spring wheat germplasm targeted for favorable irrigated areas in Egypt and also for the low latitudes of CWANA region. To optimize the management of scarce water resources, together with community participation, a project on "Options for coping with increased water scarcity in agriculture in WANA" developed and tested water management options in Egypt like raised-bed planting. Encouraged by the water saving performance of raised-bed system displayed in the first phase of this project (2002-2006), the technology was further tested and fine-tuned as part of an IFAD-funded project titled "Improving the livelihoods of rural communities in the dry areas: sustainable crop and livestock management". The technology was disseminated to farmers in El-Sharkia governorate through a multi-partner project on "Enhancing food security in Arab countries". The use of raised-bed techniques in farmers' fields resulted in 25% saving in irrigation water, 30% increase in wheat yield and 74% improvement in water use efficiency (average of four years 2011-2014). A nation-wide wheat national campaign was launched by the Egyptian government in 2011-2012, supported with a government funding of 3.7 million EGP. Mass dissemination approach was adopted and 1,900 demonstration fields of raised-bed system were implemented in 22 governorates of Egypt based on the same approach used in El-Sharkia site. Total raised-bed area in El-Sharkia governorate increased from 4000 acres in 2010/2011 to 80000 acres in 2014/2015 (Table 1).

Table 1: Increase in the total raised-bed area in El-Sharkia governorate



Achievements of the Wheat Improvement Program:

- Considerable progress was made in identifying superior lines with high yield potential and desired attributes for Egypt and CWANA irrigated environments through selection of segregating populations and subsequent advanced lines under raised-bed planting.

- Multi-location screening and yield evaluation in a north to south heat-stress gradient at six sites in Egypt (Sakha and Gimmeza in North, Sids and Fayoum in Middle and Mataana and Kom-Ombo in South) and two main sites in Sudan (Dongla in north and Wad Medani in central Sudan) resulted in the identification of many high yielding elite lines adapted to irrigated and favorable as well as heat stress environments. It was observed that some promising lines have the potential of being future varieties in Egypt and other countries.

- Five promising bread wheat lines were promoted for on-farm trials. In 2013/14 season, three Bread Wheat and four Durum Wheat elite lines proved superior to others. These improved genotypes of wheat have shown yield potential of more than 10 t/ha, which turned out to be 10-20% higher than the best checks (Sids 12 and Misr 1).

2.2 Legume Improvement Program

Background:

Faba bean is traditionally an important food legume crop in Egypt. Collaboration of ARC and ICARDA is, therefore, quite strategic for increasing production of faba bean in the country. Currently, almost 50% of faba bean is imported. However, national goal is to attain self-sufficiency, despite a decline in the area of cultivation from 150,000 ha in 1980s to around 50,000 ha at present. Hence, efforts towards productivity enhancement are likely to achieve both food and nutrition security at the national level. As faba bean is grown under irrigated conditions in Egypt, there is considerable scope of increasing its productivity. As such, ARC and ICARDA decided to improve the productivity of faba bean under this program.

Faba bean research under ARC-ICARDA collaborative program is building on and adding to the achievements of EU-IFAD funded project in Egypt on "Enhanced small-holder wheat-legume cropping systems to improve food security under changing climate in the drylands of West Asia and North Africa". The technological package developed in this project resulted in an average increase in yield of around 23% as shown in Table 2 with an increase in farmers' net revenue of 3852 Egyptian Pound/ha (Table 3).

Table 2: Performance and gains with the used technology package (EU-IFAD Project)

Agro-ecological Zones	Governorates	No. of Demos.	Seed yield (t/ha)		Differences	
			In-demo	Out-demo	t/ha	%
North Egypt	Kafr Al-Sheihk	5	4.13	3.38	0.75	21.3
	Dakahlia	14	5.23	4.45	0.78	17.9
	Sharkia	20	4.29	3.26	1.06	31.3
New lands	Nubaria	15	3.64	3.14	0.50	16.7
Upper Egypt	Assiut	10	4.65	3.80	0.95	25.1
Total / Average		64	4.39	3.61	0.81	22.46

Table 3: Economic benefits of the used technology package (EU-IFAD Project)

Parameters	Recommended package	Farmer's practices	Difference
Seed rate (kg/ha)	80	125	-45
Yield (kg/ha)	3706	3447	259
Total costs (LE/ha)	5301	7970	-2670
Revenue of main crop (LE/ha)	18178	16472	1705
Revenue of secondary product (LE/ha))	1070	1593	-524
Total revenue (LE/ha)	19247	18065	1182
Net Revenue (LE/ha)	13947	10095	3852
Costs/Revenue Ratio	28%	44%	-17%

Achievements of the Legume Improvement Program:

- Four faba bean varieties were released in Egypt. These were: Misr3, having partial resistance to Orobanche and chocolate spot; Sakha 4, possessing chocolate spot resistance and Nubaria 2 and Nubaria 3, both being low water requiring varieties. Ten faba bean promising lines were also identified as early and high yielding genotypes, whereas 180 faba bean lines were selected for high yield and earliness under late planting condition. One extra early faba bean line, maturing in 120 days, was also identified.
- 250 faba bean lines were evaluated for herbicide tolerance against Metribuzin. Four lines have shown tolerance.

- Hybridization work for Orobanche resistance and terminal heat tolerance was also initiated, and sources for faba bean necrotic yellow virus resistance were identified for hybridization with released varieties.
- Evaluation of some chickpea and lentil varieties was also taken up recently.
- Seed multiplication of newly released varieties was taken up in 2011. Last year, 15.35 tons of seed of four new varieties (Misr3, Sakha4, Nubaria2, and Nubaria3) were distributed across the country. In 2013, the seed production was 130 tons, which was around 12% of the total seed distributed in Egypt.
- A field day was conducted for the first time at Sids Research Station in 2014 to promote new faba bean varieties in middle Egypt, in which 52 farmers participated, including three women.
- Field visits were organized at different locations in Sids, Sakha and Nubaria from 2009 to 2011 to evaluate the elite lines in advanced yield trials, resulting in the release of four varieties. Field visits were also organized at Gemeiza station to evaluate differential response to Orobanche in 2012 and 2013. Similarly, field visits with national partners were organized in 2014 to see the performance of faba bean under raised-bed planting in El-Sharkia.
- Twelve food legume scientists participated in the training course on experimental design and statistical analysis conducted in Cairo in 2012, whereas two scientists from ARC, Cairo attended a training course at ICARDA's Terbol station in Lebanon from 8-19 April, 2013.
- Five screen houses were established at Sids Research Station for the maintenance of breeding lines and for hybridization work during the last two growing seasons (2013 and 2014). A threshing machine was made available in 2013. Also, the seed preparation area and the seed storage facilities were renovated in 2014.
- 10 faba bean promising lines were identified as early and high yielding genotypes.
- 90 faba bean breeding lines were evaluated under late planting at Sids using alpha design with two replications. 27 faba bean lines with early flowering and maturing time out were identified and selected for further evaluation during 2014/2015 cropping season.
- 190 F3 bulk populations were evaluated under late planting using unreplicated design. 45 F3 populations having early flowering and maturing date were selected for further evaluation during 2014/2015 cropping season.
- 166 advanced faba bean breeding lines were evaluated under late planting at Sids using unreplicated design; 40 of them were selected for further evaluation during 2014/2015 season.
- Studies of seven different Orobanche biotypes in order to identify the most virulent in pot experiments were conducted at Giza during 2013/2014 season. The results showed that Mallawi biotype was the most virulent and therefore sick plots for Orobanche resistance at Mallawi and Sids were established. 420 faba bean breeding lines were planted last November in Mallawi and Sids in the established sick plots with virulent Orobanche biotypes.
- 16 faba bean crosses combining, Orobanche, earliness, high yield and faba bean necrotic yellow virus were initiated. The F1 seeds will be harvested during 2015 season.
- 50 faba bean breeding lines were evaluated for their BNF capacity using two rhizobia. Out of them 10 were highly nitrogen fixer genotypes.

200 faba bean breeding identified previously for earliness and high yield were multiplied under screen houses at Sids during 2014 season. Those lines were sent to Terbol, Lebanon for shuttle breeding and evaluation under summer season. 20 lines were identified for earliness and high yield at Sids and were shared with different NARS through the International nursery system.

2.3 Water and Land Productivity Program

Background:

The main objective of this program was to enhance agriculture productivity and production through sustainable and efficient use of land and water resources so as to enhance smallholder farmers' livelihoods. This goal was to be achieved through the following well thought out objectives:

- Optimizing on-farm water and land productivity in irrigated agriculture in Egypt through advanced geo-informatics.
- Improving land and water productivity using fresh and marginal-quality water in irrigated systems.
- Developing optimal conjunctive use of irrigation and shallow ground water system.
- Preventing water pollution through the use of best on-farm and off-farm management practices, like the use of treated wastewater and grey water for irrigation.
- Developing an adaptable package for better management of irrigation water and fertilizers under seasonal water shortage in poor-fertilized soils, development and use of crop production function and models.
- Developing strategies that address institutional and technical barriers associated with the management of main and branch canals and assessing the effectiveness of collective action in the functional operation of water user associations (WUAs) at the mesqa and branch canal levels. This objective is being achieved in collaboration with IWMI.
- Ensuring funding for national on-farm water management staff to coordinate research and capacity building activities through a multidisciplinary team from ICARDA and the Agricultural Research Center (ARC) and other National Agriculture Research Systems (NARS) of Egypt on improving water productivity in irrigated agriculture.

Research under Water and Land Productivity Program is building on and enhancing the achievements of other water-related projects implemented in Egypt such as Water Benchmarks of West Asia and North Africa (WANA), and Management of Water and Salinity in the Nile Delta.

Main findings of the Water Benchmarks Project

The main findings of the Water Benchmarks Project in Egypt are summarized below:

- The results of the on-farm trials showed that the recommended irrigation techniques are simple practices that can be easily implemented by the farmers. They can lead to significant increase in the yield, crop water productivity, and water saving as compared to the farmers' current practices.

- Deficit irrigation is a technique that showed a beneficial effect in maximizing crop water productivity. The results of the trials carried out in the selected sites (old lands, new lands, and marginal salt-affected lands) showed that the implementation of such a technique where a relatively high proportion of the water applied is saved did not result in any significant losses in yield for the major crops. Deficit irrigation tested in farmers' fields saved water (21%) and resulted in yield reduction of only 2%, as shown in Table 4.

Table 4: Effect of interventions on the amount of water applied and on wheat yields in old land sites

	Amount of water applied (mm)			**Wheat yield (t/ha)**		
Farm	Farmers' practices	Req.	70% of req.	Farmers' practices	Req.	70% of req.
1	540	556	436	9.429	9.321	9.464
2	557	550	430	7.607	8.321	7.393
3	511	503	396	7.75	7.679	6.646
4	540	527	420	9.44	8	10.44
Average	536.9	534.1	**420.5**	8.56	8.33	**8.44**

Req.: requirement

Raised-bed technique showed very satisfactory results in the different sites (old and marginal lands) investigated under cropping with the main winter crops (wheat and berseem) and the summer ones (corn and cotton). Mechanized raised-bed technology helped wheat growers to increase yield by 20% and to save the applied water by 25% (Tables 5 and 6).

Table 5: Impact of mechanized raised-bed technology on wheat grain yield

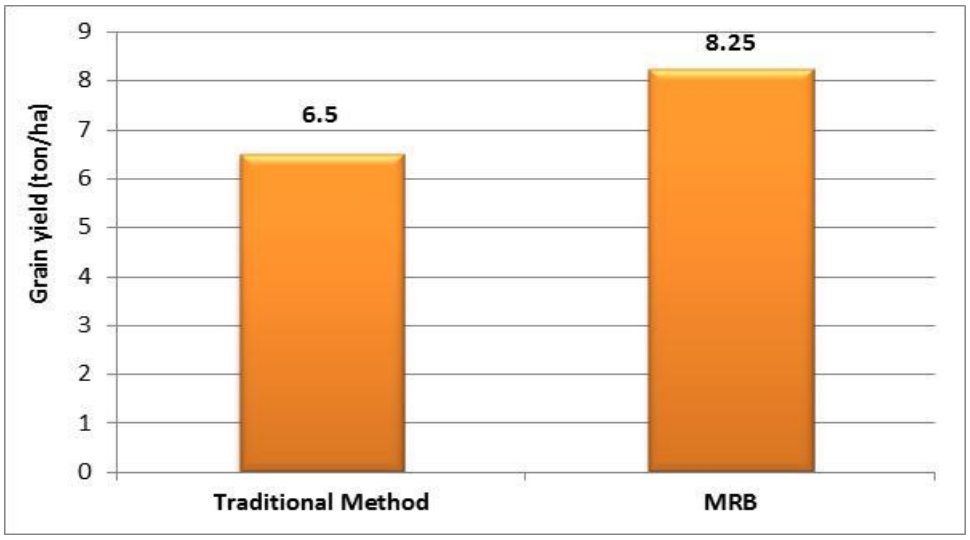
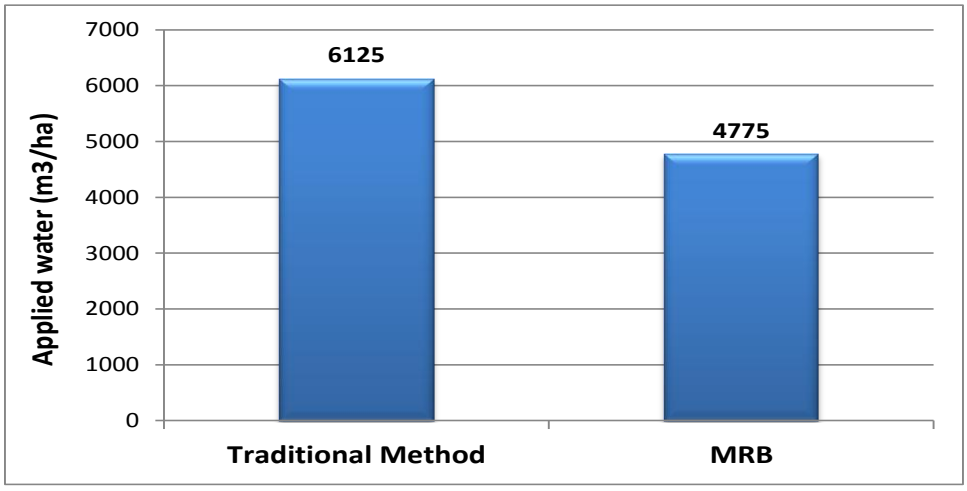


Table 6: Impact of mechanized raised-bed technology on applied water



Key results of the project on Management of Water and Salinity in the Nile Delta

The key results of the ACIAR-funded project on "Management of Water and Salinity in the Nile Delta" are summarized as follows:

- Field experiments were conducted to understand the linkages between water management practices and salt movements with control drainage at different levels. The analysis of the results concluded that controlling the drainage at 40 cm depth will lead to significant water savings.
- Field experiments were carried out during three cropping seasons (summer season 2013, winter season 2013-14 and summer season 2014) to evaluate sustainable interventions to combat degradation associated with salt accumulation. Results indicated that the application of gypsum combined with mole drain, farmyard manure, bio-fertilizer and ammonia gas achieved the highest grain and straw yield.
- Constructing Mole drains at 4m spacing and 60cm depth was found to be very effective in reducing the salinity in the root zone.
- There is usually no single way to control salinity, therefore several practices should be combined into a package that functions satisfactorily. This package should be field tested under farmer conditions. Experiments to evaluate the effect of tile drain spacing (narrow and wide) with and without mole drains under farmer conditions concluded that introducing the mole drain to heavy clay salt-affected soils improved the efficiency of the wider spacing drainage system and increased the yield (Table 7).

Table 7: Rice yields and its components as affected by various drainage and irrigation treatments

Treatments	plant height (cm)	panicle length (cm)	1000 grain weight (g)	grain yield (ton/ha)	straw yield (ton/ha)
control	108	15	16.66	4.021	5.024
20-m spacing without mole	110	15.3	17.44	4.543	4.976
20-m spacing with mole	109	15.3	17.42	4.600	5.024
40-m spacing without mole	108	15	16.9	4.086	5.000
40-m spacing with mole	108	15.3	17.09	4.421	5.024

- An economic analysis of the use of mechanized raised-bed technology concluded that the net financial benefits of this technology over conventional planting are estimated to be US$140 per acre.

Achievements of the Water and Land Productivity Program:

- Technologies developed in major production systems of Egypt (old, reclaimed, and new lands) were assessed and evaluated using the outputs of previous water related research projects and activities. For example, the use of deficit irrigation techniques, and the development and testing of new and improved raised-bed planting machine.
- "Best bet" packages of sustainable water management technologies were integrated and tested within the research sites and outside at farmers' fields through other sister projects, such as the food security project, water livelihood initiative, and IFAD crop-livestock integration projects.
- Better understanding of the water dynamics within the Nile Delta was developed.
- Technical, economic, and environmental assessments of technologies were appraised and reported.
- Policy and institutional recommendations for the implementation of appropriate water saving techniques and strategies were made.
- Area covered by raised-bed planting technology developed by ICARDA and Egypt ARC has increased from about 4,000 acres in 2010/11 cropping season to over 15,000 acres in 2011/12 and 55,000 in 2012/13 cropping season in El-Sharkia Governorate. In 2014/15, this further went up to 80,000 acres. Accelerated adoption rate by farmers was due to the economic benefits and media exposure to the technology.
- Improved artificial surface and sub-surface drainage systems were developed to contribute to improved salinity management. This allows for more efficient water use while optimizing salt leaching from the soil and facilitating Delta farmers to grow crops successfully in the future.
- An innovative planning model to help understand the impact of implementing farm-level best management practices was developed and is being verified by ICARDA and the national system as part of the national system research agenda.
- Improved surface deficit and full irrigation practices were further refined to save on applied water. This can lead to reduce current applied water amount by over 1.6 billion cubic meter per year.

- Annual report on '*Optimizing on-farm water & land productivity in irrigated agriculture in Egypt through advanced geoinformatics'* was published for 2014.
- Literature review was conducted on '*Geoinformatics and modern technology for more sustainable agriculture management to mitigate the current and potential climate change impact*'.
- Calibrated the model (AquaCrop) for estimating soil water content in effective root zone for maize and wheat crops.
- Conducted training course on farm management strategies to improve crop-water productivity using AquaCrop in cooperation with FAO, 24-28 August 2014.
- Organized three field days for small farmers and agriculture engineers to learn about modern and applied irrigation techniques and on-farm management practices to increase the overall crop yield and water productivity.
- Organized a field day for two ARC-stations to improve NARS personnel skills on soil profiling and sampling methods.
- Purchased equipment and instruments to improve the hardware capacity building and increase the accuracy of field and lab measurements.

Capacity building activities:

The conducted capacity building activities resulted in:

- 25 researchers well trained in the use of AquaCrop from 10 Arab countries (15 were Egyptians)
- 60 farmers and agriculture engineers trained in field management (all Egyptians)
- 8 NARS researchers trained in soil profiling and sampling (all Egyptians)

Publications:

- Several technical reports, Ph.D. and M.Sc. thesis, conference proceedings, pamphlets and dissemination handouts were published as an outcome of this program (http://www.icarda.org/integrated-water-and-land-management/teaser).

2.4 Livestock Biodiversity Program

Background:

Under the collaborative program of ARC-ICARDA, the Animal Production Research Institute (APRI) launched in 2009 a research program for identifying and developing abiotic stress tolerant desert Barki sheep and goat populations in the Coastal Zone of Western Desert (CZWD) in Egypt. This program was aimed at supporting livelihood and resilience of desert communities to hot dry conditions. A research project was also undertaken between APRI, ICARDA and CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement, French Agricultural Research Centre for International Development) to understand the role of livestock in reducing vulnerability and

increasing adaptation in the agro-pastoral systems of the CZWD (Matrouh) and in the integrated crop-livestock systems in the new reclaimed lands of west delta. The analysis shows the relative contribution of farm and off-farm activities to total annual family net income and per capita annual income in US$ over the period March 2010 to February 2011 for each agro-ecological zone in the Coastal Zone of the Western Desert as shown in Table 8 (sample: 181, survey 2011).

Table 8: Contribution of farm and off-farm activities to total annual family net income

Zone	Income from livestock to total income (%)	Income from crops to total income (%)	Off farm income to total income (%)	Annual family income (US$/family)*	Per capita income (US$/person)
Rainfed zone	35%	49%	16%	12,722	1.76
Newly reclaimed land	62%	30%	8%	24,554	3.46
Siwa oasis	28%	49%	23%	10,061	1.77

Achievements of the livestock biodiversity program:

Under this program, significant progress was made by a team of experts representing different disciplines and in collaboration with ICARDA and Iowa State University (ISU). Specific achievements are detailed below:

i) The biological study phase (2009-2012)

- Both local sheep and goats showed tolerance to abiotic stresses under hot and dry conditions with detectable individual variation in both the species. Physical exercise under direct solar radiation (simulating summer grazing in poor rangelands) revealed individual variation between individual animals. Desert Barki goats seem to be more tolerant to abiotic stress under hot and dry conditions than the desert Barki sheep.
- An animal heat tolerance index (AHTI) was developed based on the changes in five physiological parameters, rectal temperature (RT), respiration rate (RR), minute ventilation volume (MV), tidal volume (TV), and metabolic rate (MR) assuming the: a) stages of physiological responses to heat stress as defined by Silanikove (2000) and b) differentiation between respiratory activities (shallow rapid and slower deeper panting) as defined by Hales and Webster (1967). The index was used to identify high (HT) and low (LT) heat tolerant animals from a total of 195 Barki sheep and 169 Barki goats that had been exposed to heat stress in July and August 2014 (walk 7±.25 km under direct solar radiation from 12:00 pm to 3:00 pm). From the analysis, 41% and 26.5% of the goats and sheep respectively, were categorized as heat tolerant. However, the proportion of low tolerant goats and sheep were equal (20% of the tested animals). This result confirms the previous findings that showed better adaptability of the desert goats to abiotic stress.

- No single physiological parameter was reliable enough to assess individual tolerance to abiotic stress. Different AHTIs based on the stages of physiological responses were developed to identify high tolerant and less tolerant animals in both the species.
- Five economic performance traits (four month weight, twelve month weight, body weight at exposure to stress, fertility and prolificacy) were recorded for the experimental animals and were related to the physiological parameters. Changes in RT and RR, in response to abiotic stress, showed significant correlation with the economic performance traits. Increase in body temperature and panting, with heat stress in sheep, appeared to be significantly ($P < 0.05$) related to body size and reproductive performance, especially in low tolerant animals. Goats did not show such a trend which may indicate their better production and reproduction under hot and dry conditions.

ii) The genomic studies phase (current phase)

- Preliminary results indicated association in some chromosomal regions with the tolerance performance, especially with some synteny chromosomal regions (Ovine and Caprine), e.g. 3 candidate regions at Ovine chromosome 10, and 2 signatures of selection haplotypes in Caprine chromosome 9 were reported.

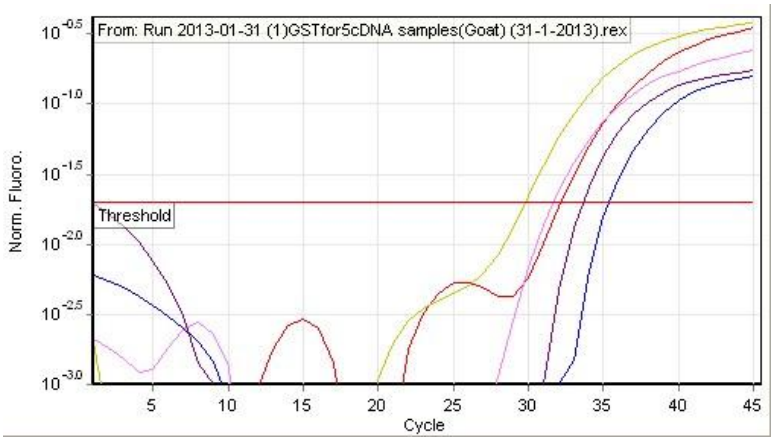
- Signature of natural selection reflects significant genomic variations between the studied local desert breeds and breeds from temperate climate (e.g. Romney sheep and La Mancha goats).

- In collaboration with Iowa State University, genotype data generated using the caprine and ovine 50K SNP BeadChips from 68 and 59 indigenous Barki goats and sheep was analyzed. Several candidate genomic regions spanning 119 genes, with evidence for selection, most likely driven by environment mediated pressure, were identified. Majority of the genes played a role in multiple signaling and signal transduction pathways involving various cellular and biochemical processes. Selection signatures spanning several genes, which directly or indirectly influence traits for adaptation to hot and arid environments, such as thermo-tolerance (melanogenesis), body size and development, energy and digestive metabolism and nervous and autoimmune response were identified.

- To further confirm these results, a further 760 animals (394 sheep from five populations (Barki = 181, Saidi = 72, Oasis = 62, Souhagi = 49, AHS = 30) and 366 goats from four populations (Barki = 150, Saidi = 60, Oasis = 72, Nubian = 84) were sampled and genotyped using the same SNP chips. The genotyping was financially supported by Max Rothschild from ISU. The data analysis will be done as collaboration between ICARDA, ARC-Egypt and ISU and has been initiated with the joint study visits of Joram Mwacharo and Ahmed Elbeltagy to ISU, Iowa in March 2015.

Figure 1: Results of gene expression

Quantitative Report of GST for Goat (High)



Quantitative Report of GST for Goat (Low)

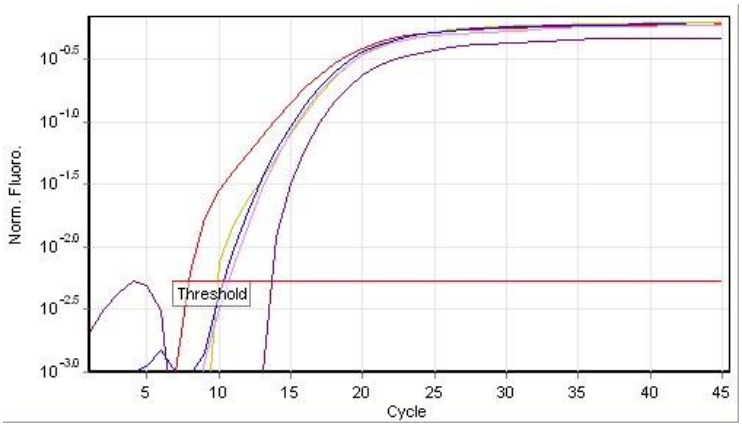
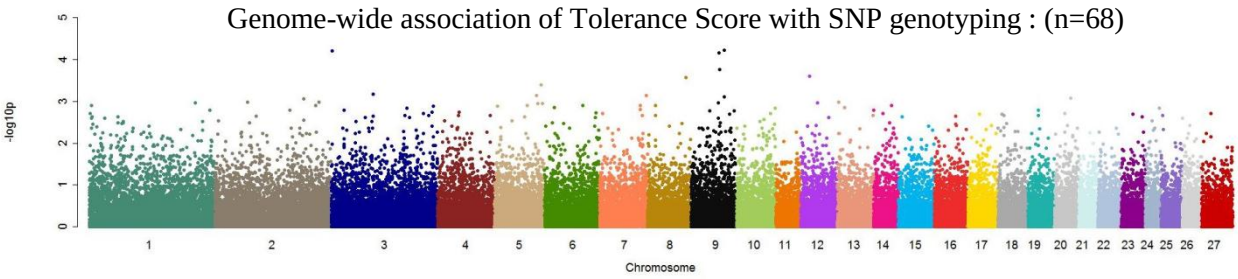
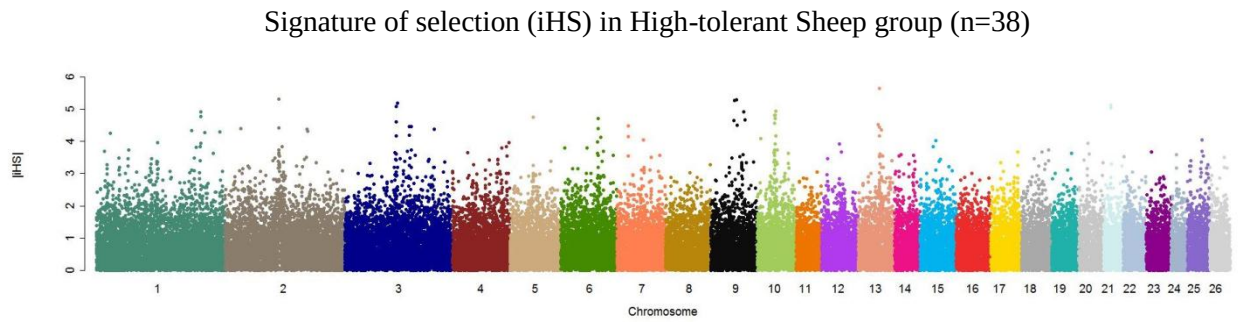
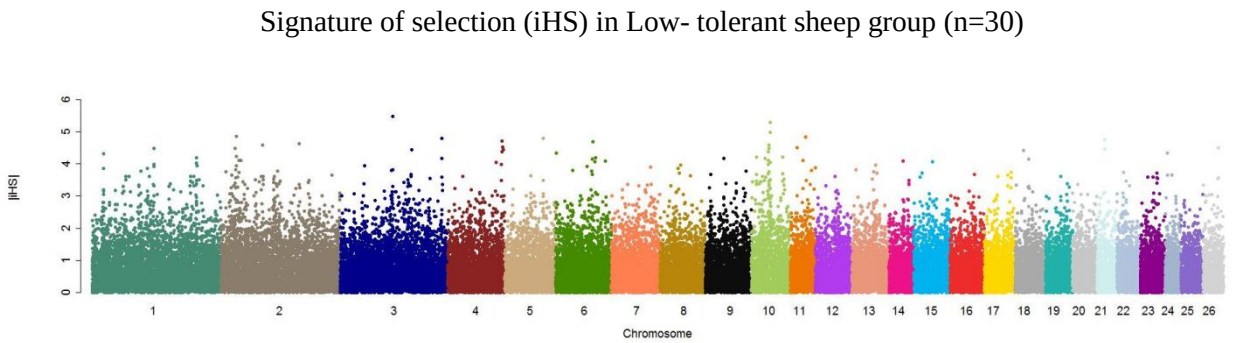


Figure 2: Genome wide association and signature of selection in Barki sheep







Impact of the program:

- Development of Animal Stress Index that can be utilized for assessing adaptation of sheep and goats to heat stress in hot and dry conditions.
- Identification of Signature of Selection and QTL associated with stress to desert conditions will be utilized for sorting the sheep and goat populations in the CZWD, to establish "Nucleus Flocks" of Barki sheep and goats adapted to heat stress under hot and dry conditions.

3. Publications under the ARC-ICARDA Collaborative Program

- Abd El-Rahman, R and Maalouf. F (2014). Identification of genetic variability for tolerance to metribuzin in faba bean. The 6th International Food legumes Research Conference (IFLRC VI) and the 7th International Conference on Legume Genetics and Genomics (ICLGG VII). Poster 130.
- Adel M. Aboulnaga, H.H. Khalifa, A.R. Elbeltagy, T.M.M. Abdel Khalek, , M.H. Elshafie, M.M. Anwar, and B. Rischkowsky. 2010. Tolerance to abiotic stresses in Egyptian Barki desert sheep and goats raised under hot dry conditions: Individual variations. 10th International Conference on Development of Drylands. Meeting the challenge of sustainable development in dry lands under changing climate-moving from global to local. 12-15 December 2010, Cairo, Egypt
- Ahmed R. Elbeltagy, A. Aboul-Naga, T. Abdel Khalek, M. Elshafie, and B. Rischkowsky. Tolerance to abiotic stresses in Egyptian desert sheep and goats raised under hot-dry conditions: Biological analysis to natural and acute heat stresses. 2012. XI International Conference on Goats, Gran Canaria, Spain 2012
- Ahmed R. Elbeltagy, Eui-Soo Kim, Adel M. Aboul-Naga, Barbara Rischkowsky, and Max F. Rothschild. 2014. Signatures of natural selection and initiation of GWAS. Plant and Animal Genomics Conference, 10-15 January 2014, San Diego, CA, USA
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4. South-South collaboration and spillover impacts

ARC-ICARDA wheat improvement program at Sids Research Station has become a destination for scientists from Central Asia, North Africa and Sub-Saharan Africa. Wheat cultivars developed at Sids are reaching 12 African countries through the SARD-SC Project "Support to Agricultural Research for Development of Strategic Commodities in Africa". Thus, the collaboration with ICARDA has facilitated strengthening the relationship of Egypt's research system with NARS, mainly in African countries. In 2014 season, seven screening nurseries and yield trials were made available to the participating countries under SARD-SC Wheat Project. Beneficiary countries included: Eritrea, Ethiopia, Kenya, Lesotho, Mali, Mauritania, Morocco, Niger, Nigeria, Sudan, Tanzania, Zambia, and Zimbabwe. In addition, some materials were also sent to non-participating countries like Somalia (for heat stress evaluation) and Uganda (for stem rust Ug99 screening).

4.1 Eritrea

- Identification of four high yielding, rust resistant candidates for potential release in 2015/16.

4.2 Ethiopia

- Two new candidate varieties identified for potential release in 2014/15.
- Identification of five high yielding, rust (Ug99 & yellow rust) resistant new candidate varieties for potential release in 2015/16.

4.3 Kenya

- Identification of four high yielding, rust (Ug99 & Yellow rust) resistant candidates for potential release in 2015/16.

4.4 Nigeria

- Two high yielding wheat genotypes were released.
- Three new candidate varieties identified for potential release in 2014/15.

4.5 Sudan

- Identification of four heat tolerant and high yielding candidate varieties for potential release in 2014/15.

- Scientists from ICARDA, Agricultural Research Center (ARC), National Water Research Center (NWRC), and Zagazig University developed a multi-crop raised-bed machine for small to medium sized farms that mechanized raised-bed soil formation and planting. Twelve machines were manufactured in Egypt upon ICARDA's request and shipped to NARS in Ethiopia (two units), Iraq (two units), Morocco (one unit), Nigeria (two units) and Sudan (three units). Two machines were manufactured for Egypt.

5. The Way Forward

To enhance both effectiveness and efficiency of ARC-ICARDA collaboration, an external review was conducted to assess the progress of collaborative projects in operation for the last five years. The recommendations of this external review were shared at the ARC/ICARDA bilateral meeting which was held in Cairo on 11 May, 2014. As an outcome of this meeting a five-year program (2014-2018) was proposed with two sub-programs:

5.1 Irrigated wheat-based system

This sub-program focuses on integrated wheat-based system with three components: *Wheat*, *Faba Bean* and *Water & Natural Resources Management*.

The ***Wheat component*** covers three areas:

- Crop improvement: aims at developing high yielding, good quality spring wheat cultivars tolerant to prevailing biotic and abiotic stresses in irrigated and favorable high-rainfall areas of CWANA.
- Crop management: aims at the development, verification and enhanced adoption of input-use efficient agronomic technologies to realize the potential of the improved cultivars.
- Capacity development: aims at strengthening and enhancing NARS research capabilities.

The ***Faba Bean component*** aims at developing varieties resistant to Faba bean necrotic yellows virus and to Orobanche adapted to different agro ecological zones.

The ***Water and NRM component*** aims at conducting field experiments on wheat and maize crops in three different agro-climatic zones of Egypt: (i) North Delta "Sakha", (ii) Middle Delta "Giza", and (iii) Upper Egypt "Sohag".

Activities will focus on:

- Allocating proper sowing date for wheat and maize crops in the three agro-climatic zones.

- Calibrating and validating adequate model(s) to compute and simulate crop-water productivity under current climate conditions as well as irrigation scheduling.
- Allocating the best adequate on-farm management practices for crop-water-fertility under raised-bed technique to prevent fertilizers' excessive use or deficiency.
- Assessing and studying the dynamics of water-salt-fertilizers under mechanized raised bed irrigation technique in Nile Valley and the Delta.
- Upgrading man-power skills of agronomic engineers, extension officers, and stakeholders for better on-farm management of wheat and maize crops in Nile Valley and the Delta.

5.2 Small ruminant-based rainfed system

This sub-program includes two components: *Livestock* and *Barley.*

The ***livestock component*** aims at evaluating the physiological and genomic adaptation of desert sheep and goats to environmental stress, and to improve vulnerability resilience and livelihoods of communities residing in hot and dry environments. The goal is to be achieved through the following objectives:

1. Analyzing individual biological variation of desert Barki sheep and goats for adaptation to abiotic stresses under the hot and dry conditions of the Coastal Zone of the Western Desert (CZWD).
2. Genomic analysis and assessment of signatures of selection and candidate QTL for adaptation to hot and dry conditions.
3. Establishment of an open nucleus flock of high tolerant desert Barki sheep and goats to the hot and dry conditions.

The ***barley component*** aims at stabilizing barley production and feed supply in rainfed areas of Marsa Matoruh. This will enhance livestock production by identifying adapted barley varieties and establishing pilot local barley seed production and marketing through the participation of local communities.

It is hoped that with the above proposed programs, ARC-ICARDA collaboration will be further strengthened and taken forward to newer heights.