The Role of Science and Technology in Enhancing Food Security

Mahmoud El Solh
Challenges in the Arab World in a Changing World

- The largest food deficit region in the world;
- Limited natural resources base;
- Degradation of natural resources, particularly water;
- Serious implications of climate change;
- High food prices in the world market;
- High rate of population growth;
- Very low agricultural productivity.
The Wide Yield Gaps in Arab Countries
Wheat Yield Gap Analysis in Tunisia

**Biological constraints**
- Variety
- Water
- Weeds
- Diseases and insect pests
- Soil Fertility
- Soil Problems e.g. salinity

**Socioeconomic constraints**
- Input availability
- Costs and returns
- Credit
- Prices
- Tradition and attitudes
- Knowledge
- Institutions and policies
Major Yield Gap Issues

- Efficiency of Technology Transfer
  - Use of recommended: Sowing date, seed rate, fertilizer amount, rotation, use of proper farm machinery, disease and pest management practices
- Proper targeting of Varieties / Production zones
- Timely Availability of Inputs
  - Quality Seed
  - Irrigation Water
  - Fertilizers
  - Pesticides
  - Machinery
- Government intervention and Policies: (Inputs availability & access, and Marketing issues)
Research Strategies and Approaches to Bridge Yield Gaps & Enhance Agricultural Productivity in Arab Countries
Research for Development to Enhance Food Security in Arab Countries

Research targets two major agro-ecosystems in drylands of Arab countries:

A. High potential areas: relatively high rainfall areas & irrigated agriculture

B. Low potential areas: marginal lands
A. High Potential Areas

Sources of increase in food production

- Increased productivity: 72%
- Intensive cropping: 21%
- Increase in arable land: 7%
## Potential Availability of Land for Rainfed Cultivation

*(1000 ha)*

<table>
<thead>
<tr>
<th>Region</th>
<th>Total area</th>
<th>Area &lt; 6 hours</th>
<th>Area &gt; 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Saharan Africa</td>
<td>201,761</td>
<td>94,919</td>
<td>106,844</td>
</tr>
<tr>
<td>Latin America and Caribbean</td>
<td>123,342</td>
<td>93,957</td>
<td>29,387</td>
</tr>
<tr>
<td>Eastern Europe and Central Asia</td>
<td>51,136</td>
<td>43,734</td>
<td>7,400</td>
</tr>
<tr>
<td>East and South Asia</td>
<td>14,769</td>
<td>3,320</td>
<td>11,450</td>
</tr>
<tr>
<td>Middle East and North Africa</td>
<td>2,716</td>
<td>2,647</td>
<td>71</td>
</tr>
<tr>
<td>Rest of world</td>
<td>52,134</td>
<td>24,554</td>
<td>27,575</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>445,858</strong></td>
<td><strong>263,131</strong></td>
<td><strong>182,727</strong></td>
</tr>
</tbody>
</table>

*Note: Data reflects potential supply of land in areas with a population density less than 25/km².*

*Source: Fischer and Shah 2010*
Bridging the Yield Gap in High Potential Areas: Sustainable Agricultural Intensification

Agricultural intensification would bridge the yield gap and is very important in Arab countries to enhance food security. However, it is a serious threat to the environment and natural resources (biodiversity, water, land, and soil) unless it is practiced in a sustainable manner particularly in dry areas.

Thus, to bridge the yield gap the trend should and will be towards.....

Sustainable Agricultural Intensification of Production Systems in favorable conditions of dry areas and consequently towards Agricultural Modernization & Sustainable Agricultural Development
Bridging the Yield Gap in Arab Countries: S & T and Sustainable Agricultural Development

Science-based technological change developed through agricultural research and technology transfer is the key force for enhancing food security in Arab countries.

The challenge in the Arab countries is how to produce more with less.

How science and technology can do that?
The Integrated Approach for Sustainable Agricultural Development

- Sustainable Natural resource management and inputs
- Crop & livestock genetic improvement
- Integration at field and farmers levels
- Socio-economic & policy, and institutional support
The Power of Science and Technology to Enhance Food Security
Examples Thematic Research
Water Management Research:

**Enhancing water productivity & water use efficiency**

At the basin level:
- Competition among uses (environmental, agriculture, domestic)
- Conflicts between countries
- Equity issues

At the national level:
- Enhancing food security
- Reducing food imports
- Socio-political implications

At the farm level:
- Maximizing economic return from water use
- Transitioning subsistence farming to market oriented economy

At the field level:
- Maximizing WUE, productivity & income
Research Benchmark Sites for Integrated Water & Land Management

Supported by AFESD, IFAD and OFID
Implementation in Three Agro-Ecologies

Rainfed Areas

Irrigated Areas

Marginal Lands
Enhancing water productivity through:

- Modernization of irrigation systems and improving the efficiency of surface irrigation
- Modifying cropping patterns to enhance water productivity and income
- Supplemental irrigation (systems and management)
- Macro- and micro-water catchments (Vallerani and other types)
- Deficit Irrigation as a water management strategy for the water scarce areas
- Watershed management
Crop Genetic Improvement:
Conventional Plant Breeding
Biotechnology Tools

- Genomics
- Marker Assisted Selection
- Double Haploids
- Embryo Rescue
- Tissue Culture
- DNA Fingerprinting
- Genetic Engineering
New desirable traits for wheat identified through crosses with wild relatives

<table>
<thead>
<tr>
<th>Trait</th>
<th>T. boeoticum</th>
<th>T. urartu</th>
<th>T. dicoccoides</th>
<th>Ae. speltoides</th>
</tr>
</thead>
<tbody>
<tr>
<td>yellow rust resistance</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>leaf rust resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>earliness</td>
<td></td>
<td></td>
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<tr>
<td>high productive tillering</td>
<td></td>
<td></td>
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<tr>
<td>spike productivity</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>plant productivity</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>plant height</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>drought tolerance</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sunn pest resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Russian wheat aphid resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septoria tritici resistance</td>
<td></td>
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</tbody>
</table>
Improved Varieties Released by National Partners Using ICARDA Germplasm

<table>
<thead>
<tr>
<th>Crop</th>
<th>1977 - 2013</th>
<th>Recent 2 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Developing Countries</td>
<td>Industrialized Countries</td>
</tr>
<tr>
<td>Bread Wheat</td>
<td>111</td>
<td>14</td>
</tr>
<tr>
<td>Durum Wheat</td>
<td>230</td>
<td>6</td>
</tr>
<tr>
<td>Barley</td>
<td>186</td>
<td>31</td>
</tr>
<tr>
<td>Chickpea</td>
<td>110</td>
<td>31</td>
</tr>
<tr>
<td>Faba Bean</td>
<td>54</td>
<td>6</td>
</tr>
<tr>
<td>Lentil</td>
<td>101</td>
<td>16</td>
</tr>
<tr>
<td>Forages</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>Peas</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>814</td>
<td>106</td>
</tr>
<tr>
<td>Total</td>
<td>920</td>
<td>37</td>
</tr>
</tbody>
</table>

Estimated Net Benefit = about US $850 m / year
Crop Varieties Released

- High yield potential
- Agronomic traits: e.g. earliness, canopy architecture
- Tolerance to abiotic stresses:
  - Drought
  - Heat
  - Cold
  - Salinity
- Resistance/tolerance to biotic stresses
  - Diseases
  - Insect pests
  - Parasitic weeds
Wheat crossed with wild relatives: Synthetic wheat, tolerance to excessive drought

<table>
<thead>
<tr>
<th>Parent Variety</th>
<th>Yield t/ha</th>
<th>% recurrent parent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cham 6*2/SW2</td>
<td>1.6</td>
<td>147</td>
</tr>
<tr>
<td>Cham 6*2/SW2</td>
<td>1.5</td>
<td>138</td>
</tr>
<tr>
<td>Cham-6</td>
<td>1.10</td>
<td>100</td>
</tr>
<tr>
<td>Attila-7</td>
<td>1.3</td>
<td>-</td>
</tr>
</tbody>
</table>

Yield of “synthetic derivatives” compared to parents under drought stress (Tel Hadya 2008 -- 211 mm)
Yields (kg/ha) of promising wheat genotypes under rainfed (RF) and supplemental irrigation (SI)
Irrigated Heat-Tolerant Wheat in Sudan
The Power of Science and Technology in Sustainable Intensification of Production Systems to Enhance Food Security in Arab Countries

Examples on Integrated Approach
Bridging the wheat yield gap: Syria

Gaps between national average yields and progressive farmers' yields

- Potential for Growth in the Long Term
  - Elite Farmers/Experimental station Yield: 9.0 t/ha
  - Progressive Farm Average Yield: 6.5 t/ha

- Potential for Growth in the Medium Term
  - Irrigated: 4.2 t/ha
  - National Average: 2.8 t/ha
  - Rainfed: 1.8 t/ha

National Farm Average Yield (tons/ha)
Impact of the integrated approach in wheat production in Syria

- Formerly a wheat importer, the country became self-sufficient – and an exporter in 2000’s in spite of keep the wheat area almost the same.

- Between 1991 and 2004 wheat production rose from 2.1 million to 4.5 million tons, with a combination of new high-yielding varieties, supplemental irrigation technology and supportive policies.

- In spite of the very serious drought starting 2008, Syria continued to achieve relatively high productivity and high production.
The impact of agricultural technologies on the increase of wheat productivity in Syria

- Improved varieties: 32%
- Crop management: 23%
- Irrigation: 27%
- Fertilizers: 18%
Enhancing Food Security in Arab Countries

Focusing on Wheat Production

Partners

Algeria, Egypt, Iraq, Jordan, Morocco, Palestine, Sudan, Syria, Tunisia, Yemen,

ICARDA

Highlights on Phase I

2011-2014

Financially supported by

AFESD, KFAED, IDsb and OFID
Grain Wheat Yield (t/ha) in demonstration fields versus farmers’ fields

Average of 4 cropping seasons (2010-2014)

<table>
<thead>
<tr>
<th>Country</th>
<th>Egypt</th>
<th>Jordan *</th>
<th>Morocco</th>
<th>Palestine***</th>
<th>Sudan</th>
<th>Syria</th>
<th>Tunisia</th>
<th>Yemen **</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production system ****</td>
<td>I</td>
<td>R</td>
<td>R</td>
<td>SI</td>
<td>R</td>
<td>I</td>
<td>R</td>
<td>SI</td>
<td>SI</td>
</tr>
<tr>
<td>Improved practices</td>
<td>8.28</td>
<td>2.24</td>
<td>2.85</td>
<td>6.00</td>
<td>2.02</td>
<td>3.62</td>
<td>1.90</td>
<td>5.11</td>
<td>3.20</td>
</tr>
<tr>
<td>Framers’ practices</td>
<td>6.65</td>
<td>1.75</td>
<td>2.53</td>
<td>4.83</td>
<td>1.74</td>
<td>2.17</td>
<td>1.63</td>
<td>4.53</td>
<td>2.60</td>
</tr>
<tr>
<td>Average increase (%)</td>
<td>25</td>
<td>28</td>
<td>13</td>
<td>24</td>
<td>16</td>
<td>67</td>
<td>17</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>Maximum yield</td>
<td>10.35</td>
<td>3.45</td>
<td>4.30</td>
<td>7.50</td>
<td>2.17</td>
<td>5.37</td>
<td>2.96</td>
<td>6.96</td>
<td>4.36</td>
</tr>
</tbody>
</table>

*** R: Rainfed, SI: Supplemental Irrigation, I: Full irrigation

Average Yield Increase = 28%

Maximum Yield Increase = 75%
Enhancing Food Security in Arab Countries
Outcome Raised-Bed Wheat Production Package in ‘Sharkia’ Province, Egypt

- Reduce applied water by 30%
- Increased yields by 25%
- Reduced seed rate by 50%
- Increased WUE by 72%
- 70,000 feddan/ acres in Egypt in two
Salinity Management in Iraq:
The Integrated Approaches
(supported by ACIAR & Italy)
The Integrated Approaches to Cope with Salinity

<table>
<thead>
<tr>
<th>Scale</th>
<th>Managing Salinity</th>
<th>Living with Salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGIONAL and WATERSHED SCALE</td>
<td>$$$ FOCUS ON PEOPLE</td>
<td>$</td>
</tr>
<tr>
<td>IRRIGATION DISTRICT</td>
<td>FOCUS ON WATER MANAGEMENT</td>
<td></td>
</tr>
<tr>
<td>FIELD SCALE</td>
<td>FOCUS ON SOIL AND WATER MANAGEMENT</td>
<td>FOCUS ON PLANT MANAGEMENT AND AGRICULTURAL PRODUCTION SYSTEMS</td>
</tr>
</tbody>
</table>
Impact of Investment in Salinity Reclamation

Dujaila, Iraq

Pre-salinity reclamation period

Satellite Image
Landsat
April 1984
Impact of Investment in Salinity Reclamation

Dujaila, Iraq

Post-salinity reclamation period

Satellite Image
Landsat
April 2013
Impact of Investment in Salinity Reclamation

Dujaila, Iraq

Post salinity reclamation period - at present

Satellite Image
Landsat
April 2014
Socio-Economic and Policy Research to Enhance Food Security

Key part of any agricultural research portfolio

- Integrated approach, working closely with all research partners
- Analysis – poverty, livelihood strategies, gender
- Impact assessments
- Study of markets, policies, institutions
- Natural resource economics
B. Production System Resilience in Marginal Lands
Development of Livestock/Rangelands/Crops Production Systems
Integrated Research Approach for Livestock/Rangelands/Crops Production Systems

**Natural Resource Base**
- Cropland
- Rangeland
- Animal Genetic Resources

**Socioeconomic environment**
- Function and products
- Gender aspects

**Livestock Production System**
- Feed production and use from arable land
- Ecology and productivity of rangelands
- Characterization and sustainable use of genetic resources
- Effects of climate change
- System productivity and resilience
- Efficient management, breeding and health
- Efficiency of feeding system
- Product quality (food safety)
- Value addition

**Policy environment**
- Collective actions
- Policies & regulations
- Organization of Farmers

**Markets**
- Market opportunities
- Consumer demands
- Value chain analysis
- Market integration

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- Function and products
- Gender aspects
Integration of Crop, Rangeland and Livestock Production Systems

Successful Technologies

- On-farm feed production
- Flock management
- Barley production
- Natural pastures & rangeland management
- By-products - feed blocks
- Cactus & fodder shrubs

By-products - feed blocks

Cactus & fodder shrubs
- Characterization of indigenous breeds of small ruminants and some are highly adaptable to changes in the climate/environment;
- Community livestock breeding.
Successful Technologies in Farmers’ Fields

- Feed blocks using crop residues and agro-industrial by-products
- Improved rams
- Early weaning
- Improved barley cultivars
- Rotations of barley with forage legumes
Conclusion: What can make the difference?

- Enabling policy environment and strong political will to put agriculture as a national priority;
- More investment in science & technology and agricultural research;
- More investment in agricultural development;
- Greater priority to enhance sustainable water productivity;
- Sustainable intensification of production systems in high potential areas;
- Enhancing resilience of production systems in marginal lands or low potential areas;
- Modernization of extension and effective technology transfer mechanisms;
- Special attention to capacity development and institutional support;
- Innovative partnership & networking.
THANK YOU