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ICARDA
Science for Better Livelihoods in Dry Areas

Research Brief 2

High yielding wheat varieties with heat and drought tolerance

The Challenge

Wheat is an important food crop globally, and holds special significance in the Central and West Asia and North Africa (CWANA) region. However, wheat productivity in CWANA region, which is already very low (2 t/ha as compared to the 3 t/ha world average), is facing serious threats from impacts of climate change, such as rising temperatures, recurring droughts and floods, and emergence of new pests and diseases like stripe rust, yellow rust and stem rust (Ug99).

ICARDA's projects in collaboration with the International Wheat and Maize Improvement Center (CIMMYT), and national partners through the support of CGIAR Research Program WHEAT and bilateral funding, are developing climate smart wheat technologies with high yield and heat and drought resistance to combat the effects of climate change and enhance sustainable wheat production across the CWANA region and beyond.

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Wheat, an important food crop at the global level, is the most favoured staple food in the Central and West Asia and North Africa (CWANA) region. It is estimated that the CWANA region produces more than 100 million tons of wheat on an area exceeding 50 million hectares, which is nearly 50% of the wheat production area in the developing world.

However, biotic and abiotic stresses exacerbated by the impacts of climate change are posing a threat to the already declining wheat productivity in the region. The effects of climate change are also evident on the quality of wheat as increased heat results in early ageing with shriveled wheat grain and protein degradation.

Climate smart varieties developed by ICARDA's wheat breeding program

The wheat breeding program in ICARDA, in collaboration with the International Wheat and Maize Improvement Center (CIMMYT), and national partners through the support of CGIAR Research Program WHEAT and bilateral funding, applies both conventional and molecular breeding approaches and techniques in order to develop high yielding and widely adapted germplasm with resistance/tolerance to heat and drought stresses.

- **Marchouch + Jemaat Shaim:** Yellow rust, Septoria, drought tolerance, HF resistance
- **Sids:** Yield potential
- **Izmir:** Screening for rusts (Lab +field)
- **Kulumsa /Dz:** Stem rust, yellow rust, septoria, fusarium
- **Wadmedani:** Heat tolerance
- **Terbol:** CB, adaptation, yield potential, rusts, cold, drought (at Kheferdan)

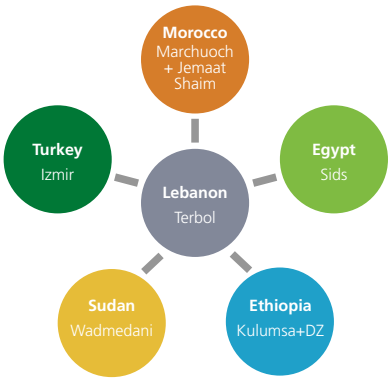

Fig. 1: Key locations for ICARDA's wheat breeding evaluations

Germplasm generations are segregated and shuttled between Terbol station in Lebanon and Kulumsa station in Ethiopia. This is followed by key location yield testing at Terbol and Kheferdan (Lebanon), Marchouch and Jemaat Shaim (Morocco), Sids (Egypt), Wadmedani (Sudan), Izmir (Turkey) and Kulumsa (Ethiopia). This enables researchers to combine yield potential and wide adaptation with resistance to biotic and abiotic stresses.

On an annual basis, the spring bread wheat program composes and distributes more than 250 elite sets of these genotypes through international nurseries and yield trials to countries in the CWANA region and beyond upon request for potential direct release or parentage purposes. The performance of some of these genotypes across key locations is indicated in Table 1. Some of the genotypes indicated in the red circle in Figure 2 combine high yield potential with drought tolerance characteristics at Terbol and Kheferdan stations in Lebanon. Figure 3 shows the performance of some of the genotypes at heading and maturity stages in Marchouch station, 2015.

Table 1: Performance of elite bread wheat genotypes across key locations in Egypt, Sudan and Morocco, 2013/14

Variety	Marchouch (Morocco) (t/ha)	Sids (Egypt) (t/ha)	Wadmedani (Sudan) (t/ha)	Average (t/ha)	Yield performance as compared to Attila-7 (%)
IBW-IMAR	7.11	11.62	3.23	7.32	119%
IBW-AMAL	6.49	12.72	2.50	7.24	118%
IBW-HAMID	7.13	9.56	3.77	6.82	111%
IBW-WAHID	7.31	10.16	2.92	6.80	111%
IBW-BRIVAN	8.98	7.81	3.05	6.61	108%
IBW-FARID	6.39	10.23	3.03	6.55	106%
IBW-OMAR	6.96	9.72	2.65	6.45	105%
IBW-AKID	6.50	9.87	2.94	6.44	105%
IBW-WIDAD	6.51	8.46	3.87	6.28	102%
IBW-TARTUS	5.89	9.39	3.40	6.23	101%
Sids-1 (Check)	5.36	10.88	2.35	6.20	101%
Attila-7 (Check)	6.19	8.40	3.86	6.15	100%
Pastor-2 (Check)	6.24	7.49	3.42	5.72	93%

Note: Morocco is under rainfed conditions, whereas Egypt and Sudan are irrigated.

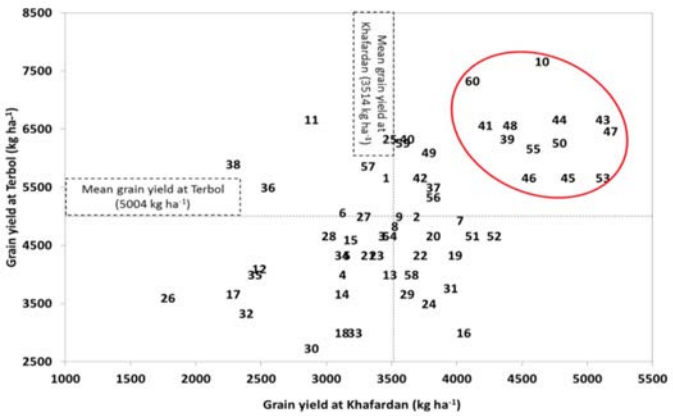

Fig. 2: Performance of different genotypes at Terbol and Kheferdan stations, Lebanon

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Table 2: Performance of the top 10 high yielding bread wheat genotypes at Merchouch (Morocco) in 2014/15 cropping season under rainfed conditions as compared to Arrehane

Var. No.	Pedigree	Yield (t/ha)	Yield performance as compared to Arrehane (%)
1004	KAUZ//MON/CROW'S'/3/SHUHA-4//NS732/HER/4/MILAN/PASTOR	7.50	195.8
1038	JAWAHIR-1/GIRWILL-5	6.16	160.8
1002	SHUHA-4//NS732/HER/3/MILAN/DUCULA	6.12	159.8
1027	SERI.1B*2/3/KAUZ*2/BOW//KAUZ/4/TRAP#1/BOW//PFAU/3/MILAN	5.71	149.0
1013	FLAG-3/ICARDA-SRRL-5	5.62	146.7
1028	KAUZ//ALTAR 84/AOS/3/MILAN/DUCULA	5.58	145.6
1014	ATTILA 50Y//ATTILA/BCN/3/PFAU/MILAN	5.56	145.2
1015	KAUZ//MON/CROW?S?/3/VEE/PJN//2*KAUZ	5.52	144.1
1037	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2	5.42	141.4
1001	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2	5.16	134.6
1016	SERI.1B//KAUZ/HEVO/3/AMAD/4/ATTILA//PSN/BOW/3/ATTILA/5/KAUZ'S'/SHUHA-15	5.15	134.4
1040	ARREHANE	3.83	100.0

The performance of the best genotype at Merchouch, Morocco, reached up to 7.5 t/ha under rainfed condition which is a dramatic gain as compared to the 3.4 t/ha yield level of the commonly grown cultivar, Arrehane. Under drought conditions (250 mm rainfall), the yield level of some of these genotypes reached up to 2.5 t/ha. Pedigree analysis showed that most of them contain synthetic hexaploid wheats (SHWs) while others possess *T. dicoccoides* in their background. Some of these genotypes have deep green leaves with early vigour and 'stay green' characters.

Table 2 shows the performance of top ten bread wheat genotypes at Merchouch compared to Arrehane, the commonly grown cultivar. The three best performing genotypes are being considered for registration by INRA (Institut National de la Recherche Agronomique), Morocco. The release of these varieties would boost wheat productivity in Morocco enormously as the currently grown cultivars such as Achtar, Arrehane, Amal and Mahadia are all susceptible to yellow rust.

Fig. 3: Drought and heat tolerant high yielding lines at early (left) and maturity (right) stages.

Through the support of Grain Research and Development Corporation (GRDC), CIMMYT and ICARDA, spring wheat germplasm were also evaluated across Australia under the CAIGE (CIMMYT-AUSTRALIA-ICARDA Germplasm Evaluation) project. Outstanding germplasm were observed in both the breeding programs (Table 3) across different locations in Australia (caigeproject.org.au) indicating the potential of the CGIAR germplasm for Australian wheat breeding programs.

Table 3: Performance of the top 20 high-yielding wheat genotypes at CAIGE nursery in Junee, Australia, 2013, under rainfed conditions

Rank	Name	Origin	Avg Yield / (t/ha)
1	1:ZIZ12	ICARDA	4.84
2	112:ZIZ12	ICARDA	4.54
3	56:ZIZ12	ICARDA	4.52
4	134:ZWB12	CIMMYT	4.44
5	53:ZIZ12	ICARDA	4.41
6	16:ZIZ12	ICARDA	4.31
7	234:ZWB12	CIMMYT	4.29
8	111:ZWW12	CIMMYT	4.28
9	44:ZIZ12	ICARDA	4.27
10	74:ZIZ12	ICARDA	4.25
11	2:ZIZ12	ICARDA	4.16
12	26:ZIZ12	ICARDA	4.14
13	76:ZIZ12	ICARDA	4.11
14	CHECK_AUS	Australia	4.11
15	124:ZIZ12	ICARDA	4.10
16	51:ZIZ12	ICARDA	4.08
17	19:ZWB12	CIMMYT	4.08
18	36:ZWB12	CIMMYT	4.05
19	218:ZWB12	CIMMYT	4.02
20	70:ZIZ12	ICARDA	4.02

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Variety release, dissemination and impact

Various varieties of ICARDA origin have been released in many countries such as Syria, Ethiopia, Sudan, Nigeria, Turkey, Iran, Uzbekistan, Tajikistan, Afghanistan, etc. The recent releases are resistant to both Ug99 stem and yellow rust diseases. These released varieties are multiplied, diffused and adopted by farmers with the proper recommended production packages.

Trends in wheat production in Syria, Morocco, Egypt and Ethiopia have shown an upward movement (Figure 4) in the past two decades. Wheat system intensification by both governmental and non-governmental organizations have played a significant role in demonstrating and diffusing wheat technologies, increasing wheat productivity and bolstering food security.

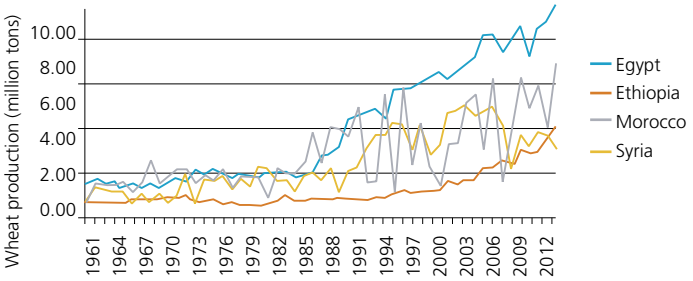

Fig. 4: Trends in wheat production in Syria, Morocco, Egypt and Ethiopia from 1961-2012

Efforts towards sustainability and capacity building

To make the wheat genetic improvement efforts sustainable, it is vital to have well-trained young scientists as part of the National Agricultural Research Systems (NARS). ICARDA has established an annual wheat improvement course in which junior and mid-career NARS scientists undergo a comprehensive hands-on training/experience and a comprehensive hands-on course on breeding for durable disease resistance, high yield potential and stability, drought and heat tolerance, end-use seed quality, and seed health issues using conventional and molecular tools.

Rapid deployment of high-yielding wheat varieties that are heat and drought tolerant, along with improved crop management technologies, such as conservation agriculture, supplemental irrigation, drip irrigation, site-specific nutrient management and integrated pest management (IPM) will help enhance sustainable wheat production across the CWANA region.

ICARDA's Crop Improvement Program

ICARDA has a global mandate for the improvement of barley, lentil, grasspea and faba bean, and a shared mandate for chickpea, bread wheat and durum wheat. With partners in more than 40 countries, ICARDA produces science-based solutions for new crop varieties (barley, wheat, durum wheat, lentil, faba bean, kabuli chickpea, grasspea, pasture and forage legumes). The Marchouch research station near Rabat in Morocco is host to a model crop improvement program that develops crop production technologies for both high and low potential agroecosystems. This research station, with cutting edge biotechnology labs, over 100 hectares of experimental fields, seed system infrastructure and a pool of world class scientists, builds on ICARDA's longstanding partnership with Institut National de la Recherche Agronomique (INRA). ICARDA has decentralized its genetic resources activities in Tel Hadya, Syria, and continues to strengthen its genebank holdings in Morocco, Lebanon and Tunisia while safely duplicating them in Svalbard in the Arctic. The crop improvement activities are well supported by facilities created at different platforms including Terbol in Lebanon, Amlaha in India and Cairo in Egypt.

A partnership of:

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CGIAR RESEARCH PROGRAM ON Wheat

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