Development and Deployment of Climate Resilient Wheat Varieties to Ensure Food Security in Africa

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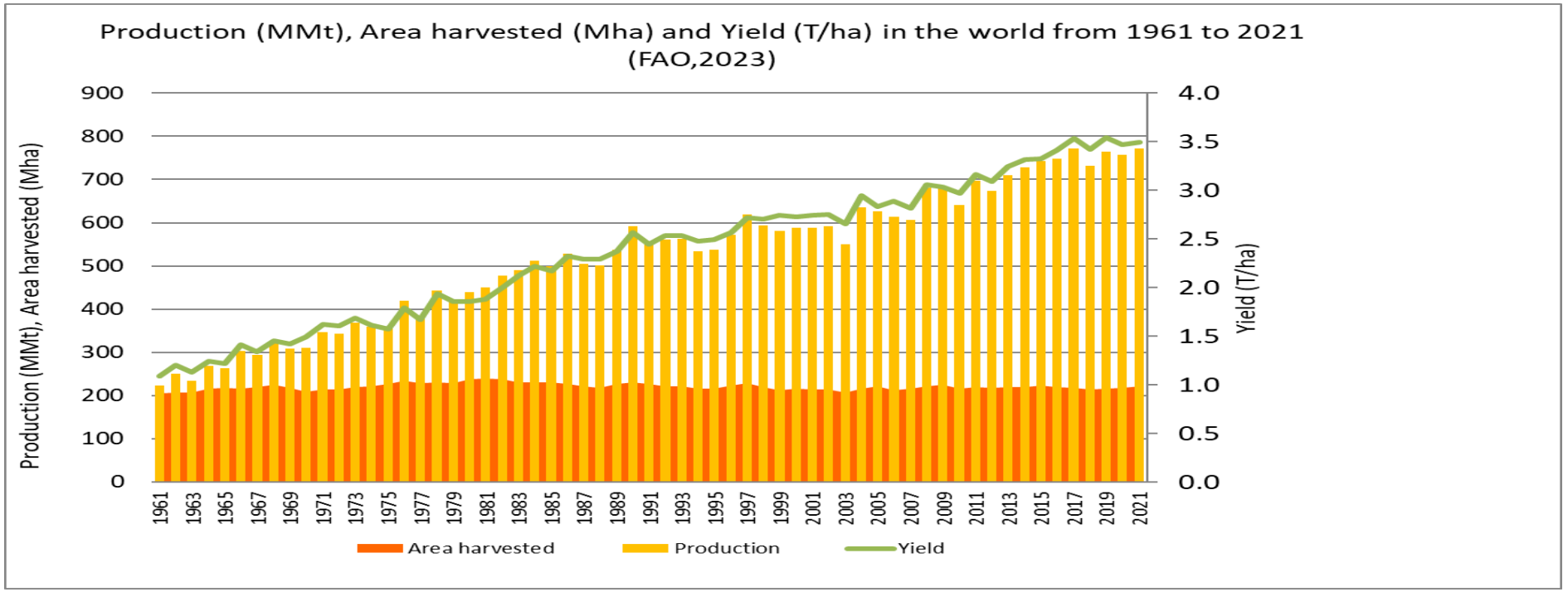
Global trends in wheat production, 1961-2022



- Wheat production has increased across years globally with out significant change in production area
- This is due to adoption of high yielding wheat varieties, fertilizers, pesticides, irrigation, machineries, favorable policy environments etc.

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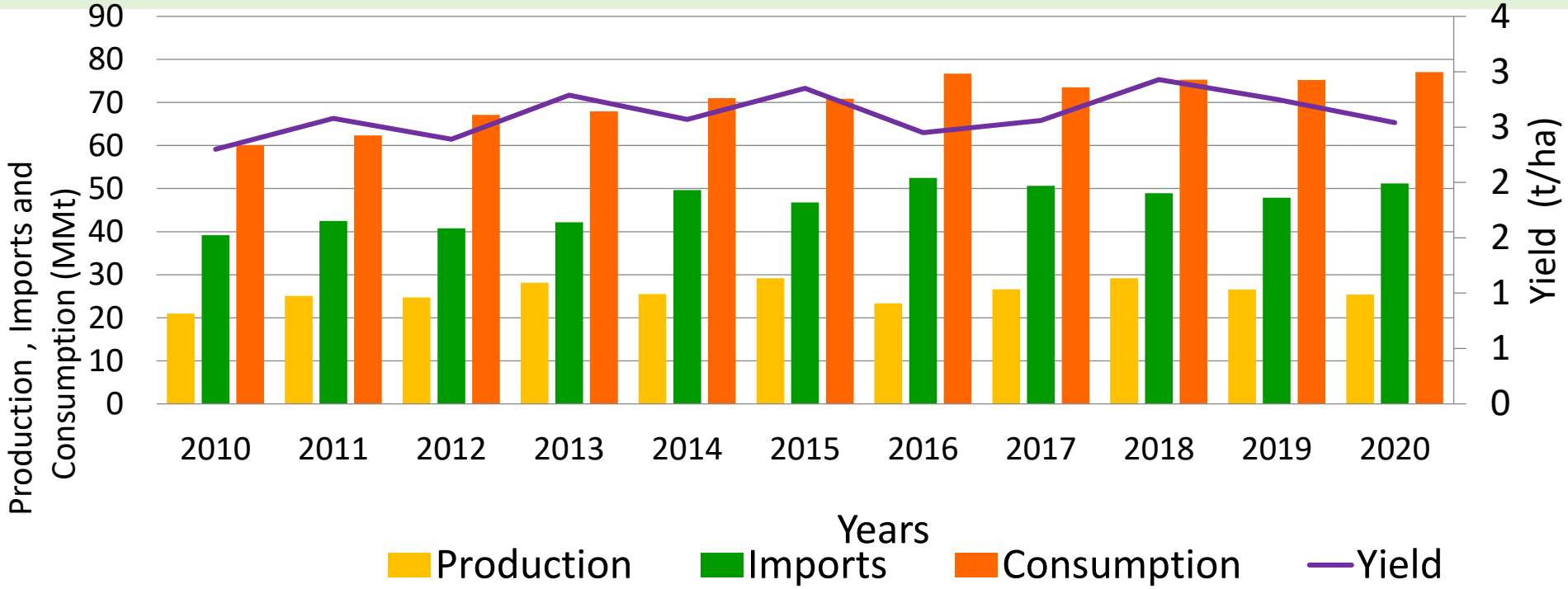
Production, Imports, Consumption (MMt) and yield (t/ha) in Africa, 2010-2020 (FAO, 2023)



*Africa grows wheat in around 10 million ha and produces 25 million tons

- Consumes 75 million tons and imports 50 to 55 million tons per year
- Average import price: 350 $/ton: about 20 billion USD/year

Challenges and Opportunities of Wheat Production in the CWANA and SSA regions

Challenges

- Biotic and abiotic stresses associated with climate change
- Poor infrastructure
- Increasing cost of inputs (seed, fertilizer, chemicals, machineries etc)
- Lack of subsidies
- Social unrest and conflicts both in Africa and beyond affects wheat production and marketing (e.g. the Ukraine-Russia conflict)

Opportunities

- Potential for wheat expansion : vertical and horizontal
- Increasing urbanization and change in food habit: demand for wheat increases
- Availability of young and productive workforce
- Huge regional market for wheat
- Potential for industrialization and job creation across the entire wheat value chain: production, processing, marketing and consumption

Rusts, Septoria, drought & heat are the most important wheat biotic and abiotic stresses affecting wheat production in the CWANA and SSA regions.

Production loss of cultivar Achtar : 100,000 T
Monetary loss : $ 30 m US dollars
Estimated Yield loss Gereck : 40%
Monetary loss : > $52 m US dollars
Syria: Cham 8, Cham 6 : 30-80 % yield loss
Ethiopia : Attila (Kubsa): 40-70% yield loss

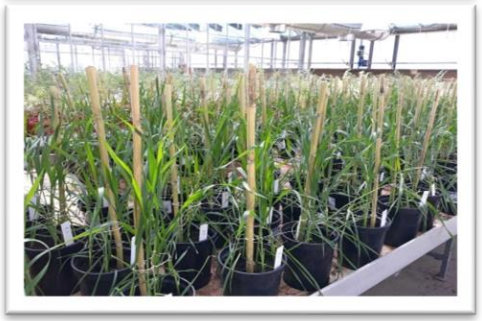
Drought causing total crop failure, Merchouch 2022

Wheat Breeding Objectives

- Development of high yielding wheat varieties with resistance/tolerance to the major biotic and abiotic stresses targeting major market segments/ agro-ecological regions
- Identification and mapping of new genes for further gene introgression and deployment
- Capacity development (short and long term training)
- Scaling of wheat technologies through research for development projects (example: TAAT)

Comparison of breeding schemes at ICARDA

Year #	Doubled haploid	Modified shuttle breeding	Shuttle breeding
Year 1	Crosses/F1 glass houses	Crosses/F1 glass houses	W x S crosses
	DH1	F2 summer season	F1 summer Terbol
Year 2		F3 winter season	F2, Sids, Egypt
	DH2 Multiplication	F4 head rows summer season	F3, Kulumsa, ETH
Year 3	PYT winter season	PYT winter season	F4 MER winter season
			F5 HR summer season
Year 4	AYT /IN winter season	AWYT/IN winter season	PYT winter season
Year 5			AYT/IN winter season

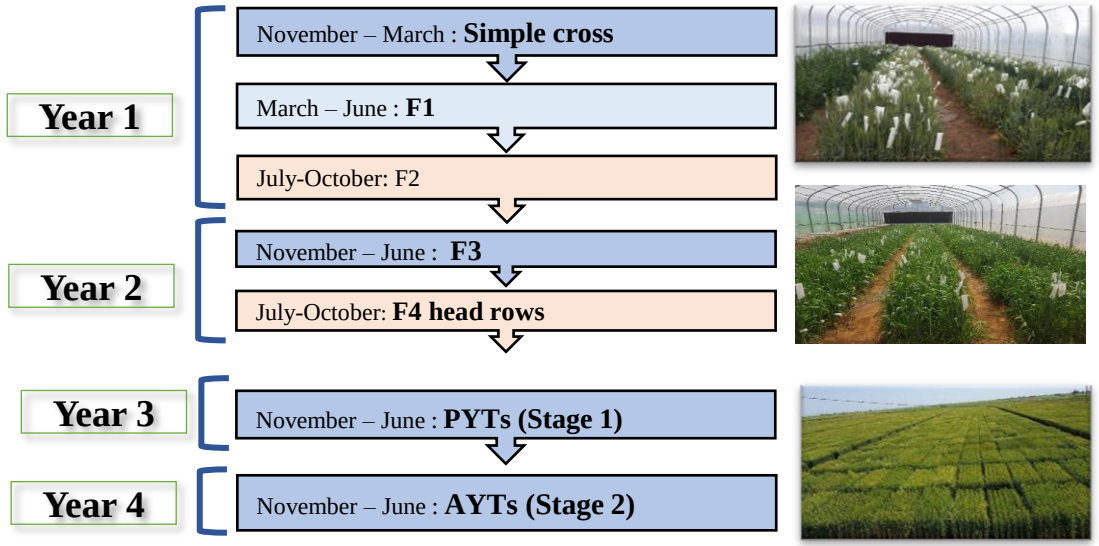


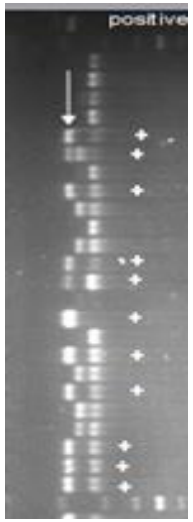
PYTs (2000-3000), AWYTs (600-1200) across key locations; GWAS, MAS, GS: We have tried GS on PYT to predict AWYT performance. Very low: 0.3%

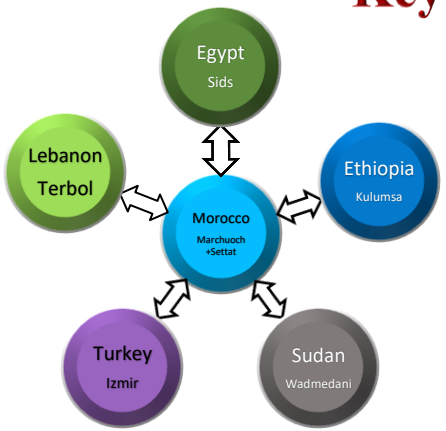
Updated Breeding Scheme

- **The rate of genetic gain, $\Delta G = i\, h\, \sigma A / T$,**

where: i = selection intensity, h = heritability in the narrow sense, σA = is additive genetic variance, L = the length of breeding cycle interval or generation.







Marchouch + Settat (PP1): Yellow rust, Septoria, drought tolerance, HF resistance

Sids (PP2): Yield potential

Izmir: Screening for rusts (Lab +field)

Kulumsa (PP3): Stem rust, yellow rust, septoria, fusarium

Wadmedani (PP4): Heat tolerance

Terbol (PP5): adaptation, yield potential, rusts, cold, drought (at Kheferdan)

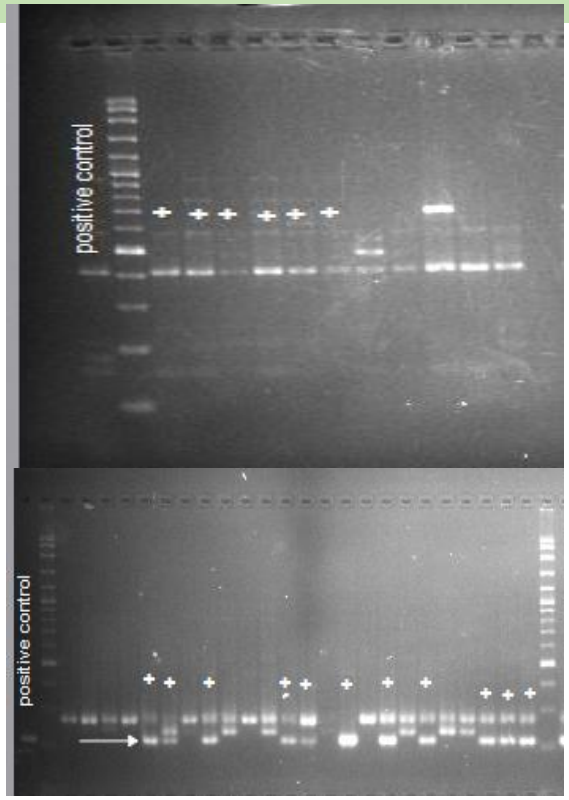
Tadesse et al 2016. In: The World Wheat Book; Tadesse et al 2022

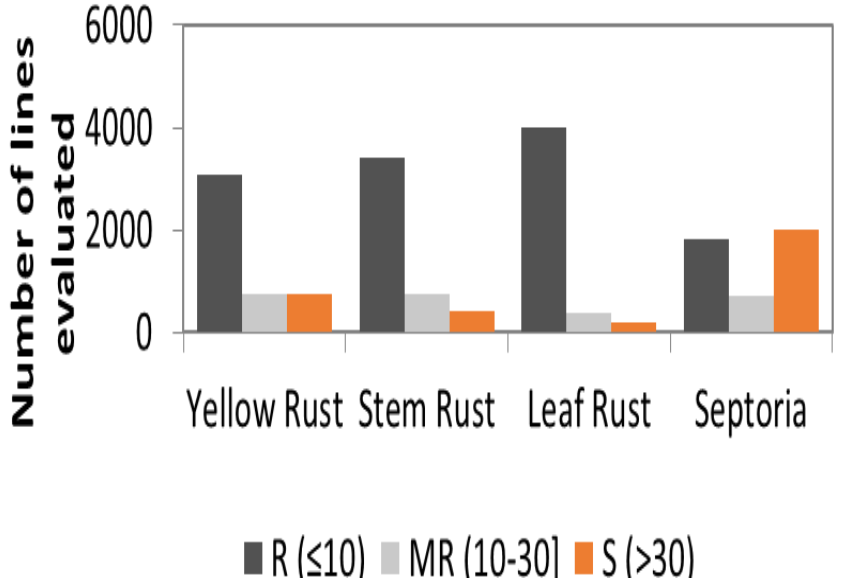
With the current modified shuttle breeding scheme, it takes only 4 years (earlier 8-10 years) from crossing to distribution of Elite genotypes to NARS. Tadesse et al 2022

Regional Rust Research Lab , Izmir, Turkey: a huge phenotyping platform which should be utilized effectively along with other global phenotyping platforms

Gene Pyramiding: MAS

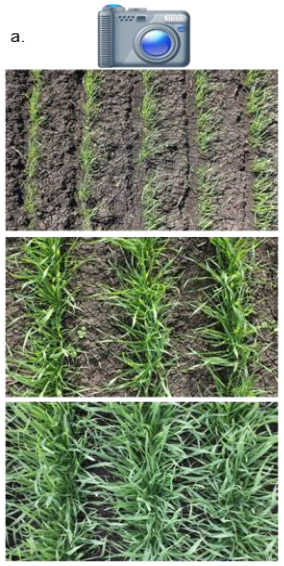
Stem rust	Yellow rust	Leaf rust	Other Genes
Pavon Sr 24+ Sr 31+Sr 50	*Yr5, Yr45*	*Lr37*	*Stb4,*
Sr 50+Sr 45 # 1	*Yr10*	*Lr34*	*Tsn1*
Sr 25	*Yr15*	*Lr67*	*Cre1*
Pavon Sr 24+ SR 26+Sr 31	*Yr17*	*Lr10*	*Cre8*
Sr 22/CO 1213	*Yr 48*	*Lr14a*	*Fhb1*
Westonia Sr 24+ Sr 26	*Yr 5+10*	*Lr24*	*H5, H13, H22*
Sr 33+Sr 45 #36	*Yr5+10+15*	*Lr23*	*H23, H26*
Angas Sr 32	*Yr48+Yr15*	*Lr22a*	
Sr 2	*Yr17+Yr48*	*Lr25*	
Sr 38	*Yr27+5+10+15*	*Lr24+Sr24*	
Sr 39	*Yr36*	*Lr19+Sr24*	
other minor genes	other miner genes		

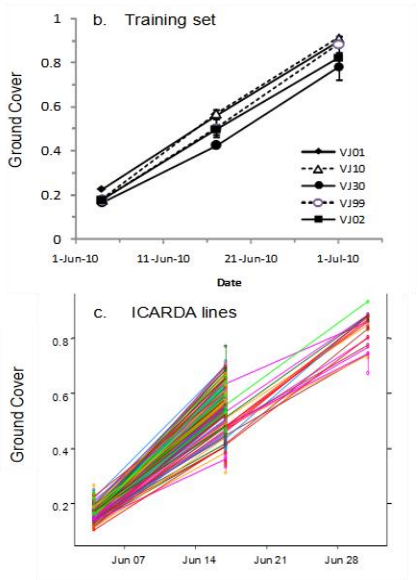


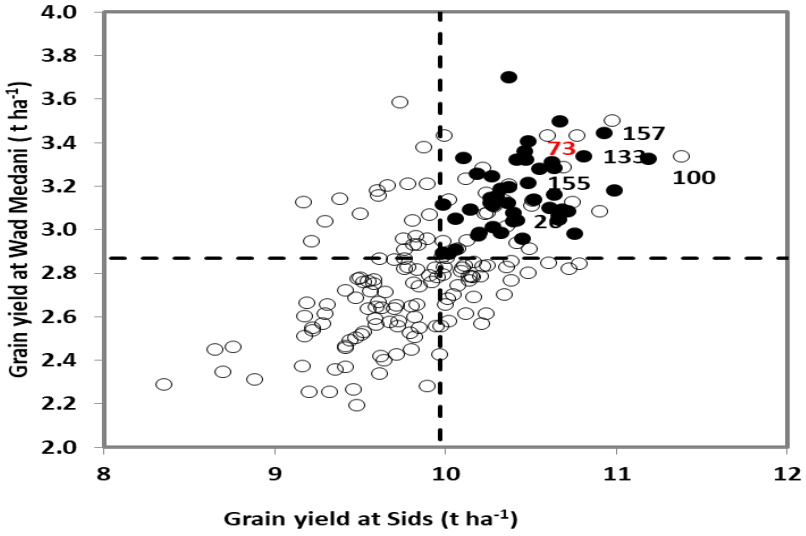


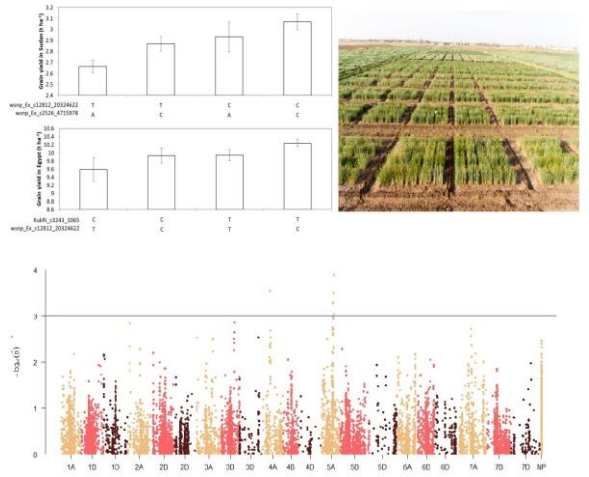
Genetic stocks from Dr Evans Lagudah

The shuttle breeding scheme with MAS enables for accelerated gene pyramiding and higher rates of genetic gain



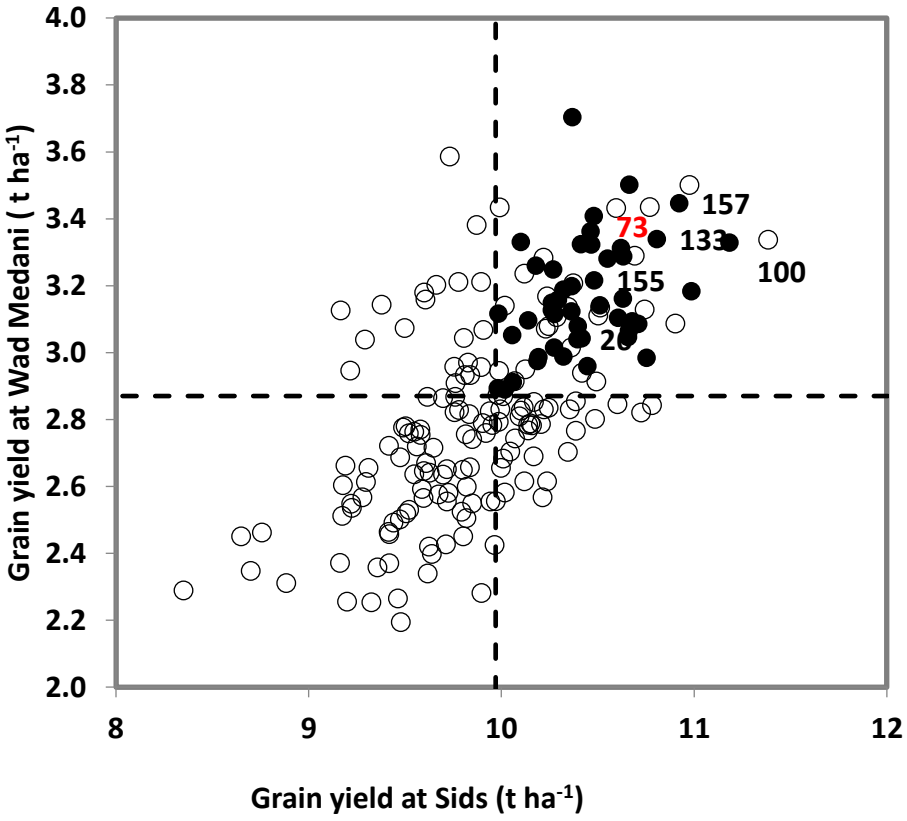


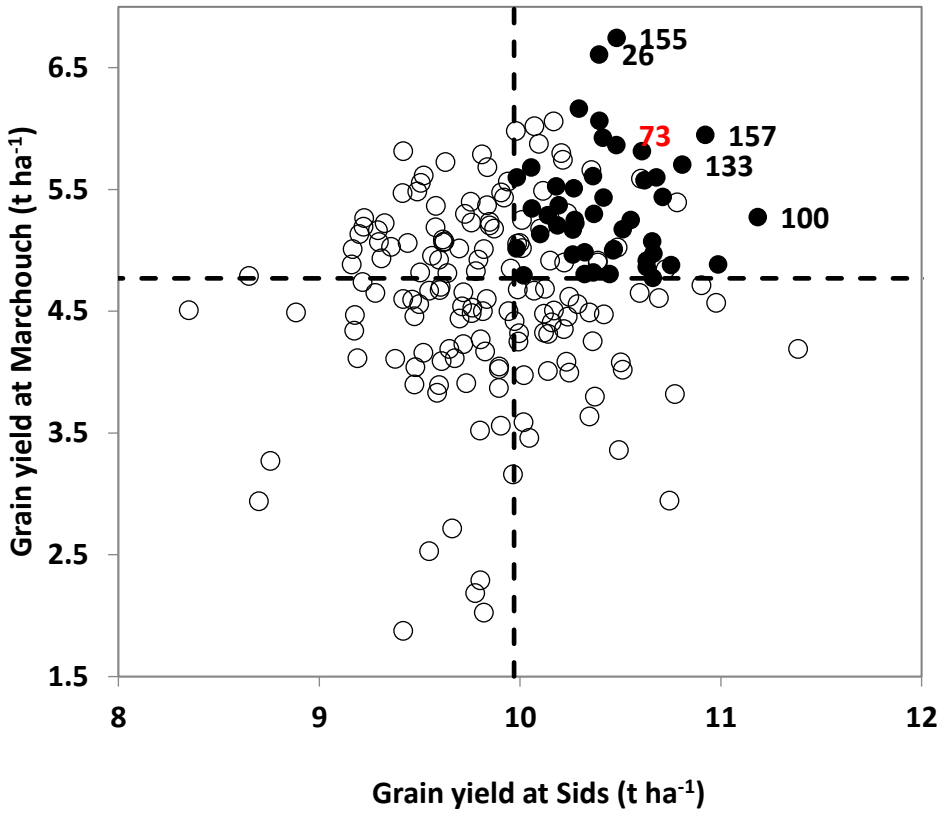




Tadesse et al. 2019, Crop Science; Tadesse et al 2022, CBGG

Yield of wheat genotypes across key locations

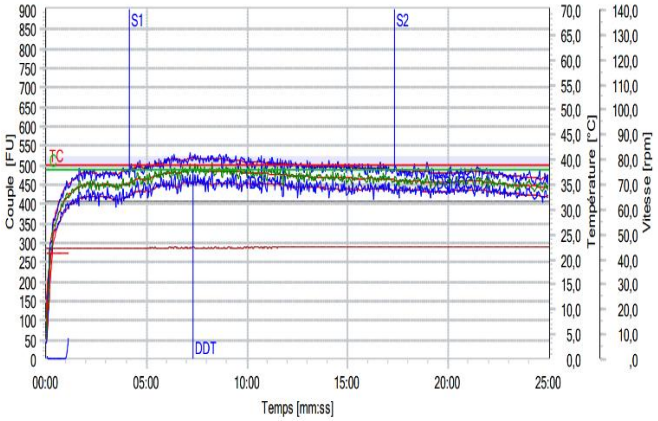


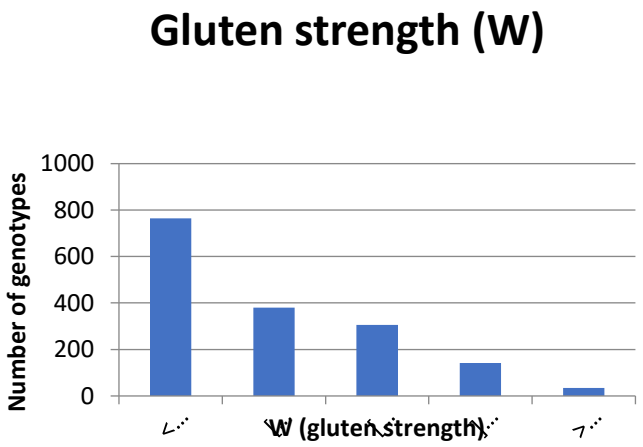


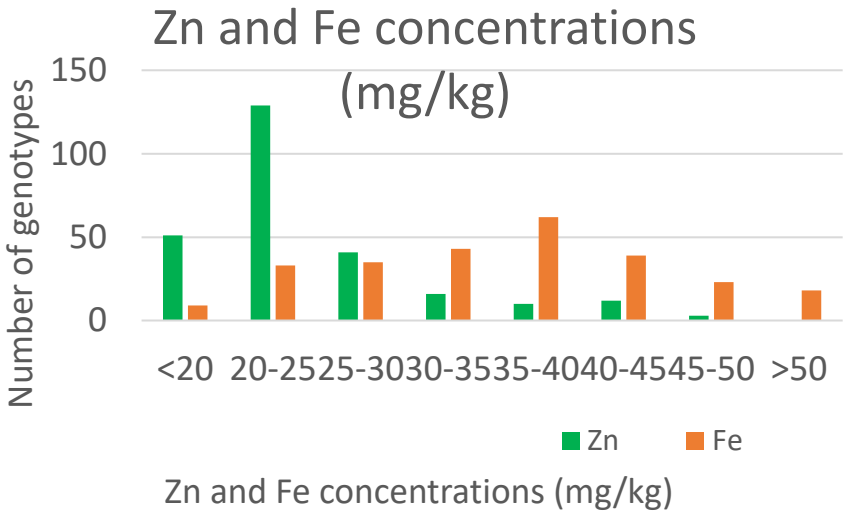
● Above average in SIDS, WM and Marchouch

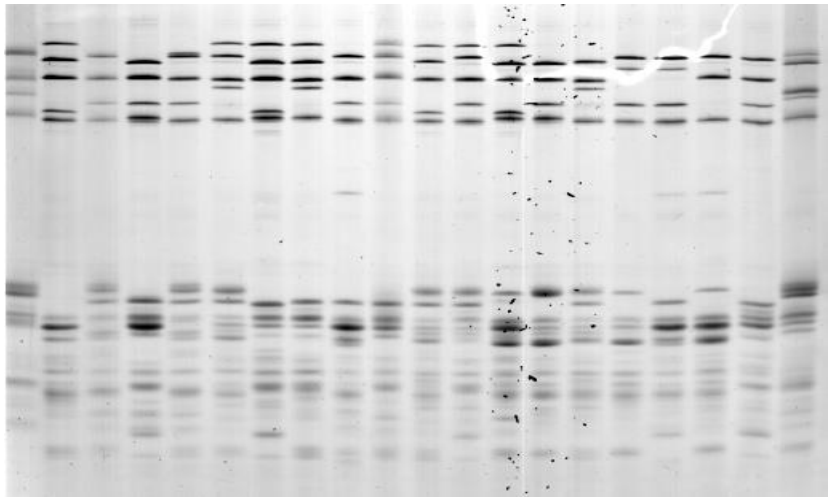
Variability of Elite spring bread wheat genotypes for Fe, Zn, Se concentrations, gluten strength (W), and HMM glutenin alleles at Merchouch

Var#	Pedigree	Zn mg/Kg	Fe mg/Kg	Se mg/kg
27488	HAAMA-3//MILAN/DUCULA	49.06	46.888	0.296
27611	ASEEL-1//MILAN/PASTOR/3/SHAMISS-3	44.40	43.046	0.348
27630	GALVEZ/WEAVER/3/VORONA/CNO79//KAUZ/4/MILAN//PSN/BOW	43.36	39.494	0.392
27811	WBLL1//TEVEE/KAUZ/3/MILAN/SHA7//POTAM*3KS811261-5	42.84	40.600	0.292
27878	SHUHA-4//NS732/HER/4/VEE/PJN//2*TUI/3/WH576/5/ICARDA-SRRL-1	41.92	50.532	0.299
27888	GIZA-164/SEKHRAH-1	41.43	50.673	0.288
27889	SW94.2690/SUNCO/4/PRINIA-1//NESMA*2/14-2/3/DUCULA	40.69	34.978	0.309
28241	GIZA-164/SEKHRAH-1	40.47	53.794	0.303









Germplasm distribution: CWANA and SSA regions and beyond

Special nurseries contribute for successful variety releases by NARS

1. International Nurseries
2. Targeted distribution of elite genotypes (5-10 genotypes; 0.5-1 kg seed)
3. Key locations partners: (Stage 1 and stage 2)
4. Project based distribution: TAAT; CAIGE

In the last 10 years, more than 70 wheat varieties of ICARDA origin have been released by the national programs in the CWANA and SSA regions.

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Hybrid wheat breeding using the BLA system: F1 seed production at Merchouch, Morocco

Capacity development in wheat breeding: Short and long- term trainings at ICARDA

2013, Cairo

2017, Rabat

2018, Rabat

2019, Rabat

Name	Sex	Country	Degree	Study area
Imane	F	Morocco	PhD	HF resistance
Alaa	F	Egypt	M.Sc	rust
Nawal	F	Algeria	PhD	Drought tolerance
Elfadil	M	Sudan	PhD	Heat stress
Molla	M	Ethiopia	PhD	Septoria
Assefa	M	Ethiopia	PhD	Heat and drought
Shaimaa	F	Egypt	PhD	Salinity tolerance
Khalil	M	Morocco	PhD	Yellow rust
Zekaria	M	Morocco	PhD	Drought tolerance
Khaula	F	Morocco	PhD	Drought tolerance
Lamyaa	F	Morocco	PhD	Drought tolerance
Tazebachew	M	Ethiopia	PhD	Yellow rust
Rania	F	Egypt	PhD	Water use efficiency

Out scaling of heat tolerant wheat through TAAT project in SSA

* Wheat production area has increased in Ethiopia (from 1.8 mha to 3mha including 1 million hactar under irrigation), Sudan, & Nigeria

- Involvement of stakeholders across the wheat value chain at the **innovation platform**
- Demand driven technology /policy development leads to faster adoption rate of technologies/policies
- Cluster farming, input supply and marketing, development of infrastructures etc, needs decision by policy makers

Summary

- Accelerated genetic gain (1.5-2%) for yield and other key traits
- Development of resistant varieties (major +minor genes) following key location and MAS approaches
- Effective utilization of the global phenotyping platforms
- Lowering the yield gap: Integrated crop management
- Increase the rate of variety replacement: Rapid seed multiplication and marketing scheme
- Public-private partnership in the seed industry
- Development of hybrid wheat for higher yield potential
- Regional collaboration and investment in wheat technologies development, production and marketing

Acknowledgements

- ICARDA's Wheat Team+ PhD students
- NARSs in the CWANA + SSA
- INRA-Morocco; ARC-EGYPT; AUB & AREC-Lebanon; EIAR-Ethiopia; ARC-Sudan and Turkey
- CGIAR, GRDC, AfDB, Arab fund, Kuwait fund

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