Spring bread wheat breeding at ICARDA: Progress for yield, drought and heat tolerance targeting CWANA and SSA regions

- W. Tadesse: Breeder
- S. Tawkaz: DH specialist
- S. El-Hanafi: Research assistant
- P. Skaf: Research assistant
- W. Shiferaw: Research assistant
- Z. Khel: Biometrician
- A. Sherif : Breeder
- I. Tahir: Breeder
- M. Baum, PD
- M. El-Bouhssini: Entomologist
- K. Nazari: Rust pathologist
- R. Sharma: Breeder
- Z. Bishaw: Seed scientist
- S. Assefa: Breeder, SARD-SC, TAAT
- H. Halila: Breeder, food security project
- A. Niane: International nursery scientist
- A. Abdellat: Molecular geneticist
- A. Hamwieh: biotechnologist
- S. Kumari, Biotechnologist
- K. Sharma: Bioinformatics

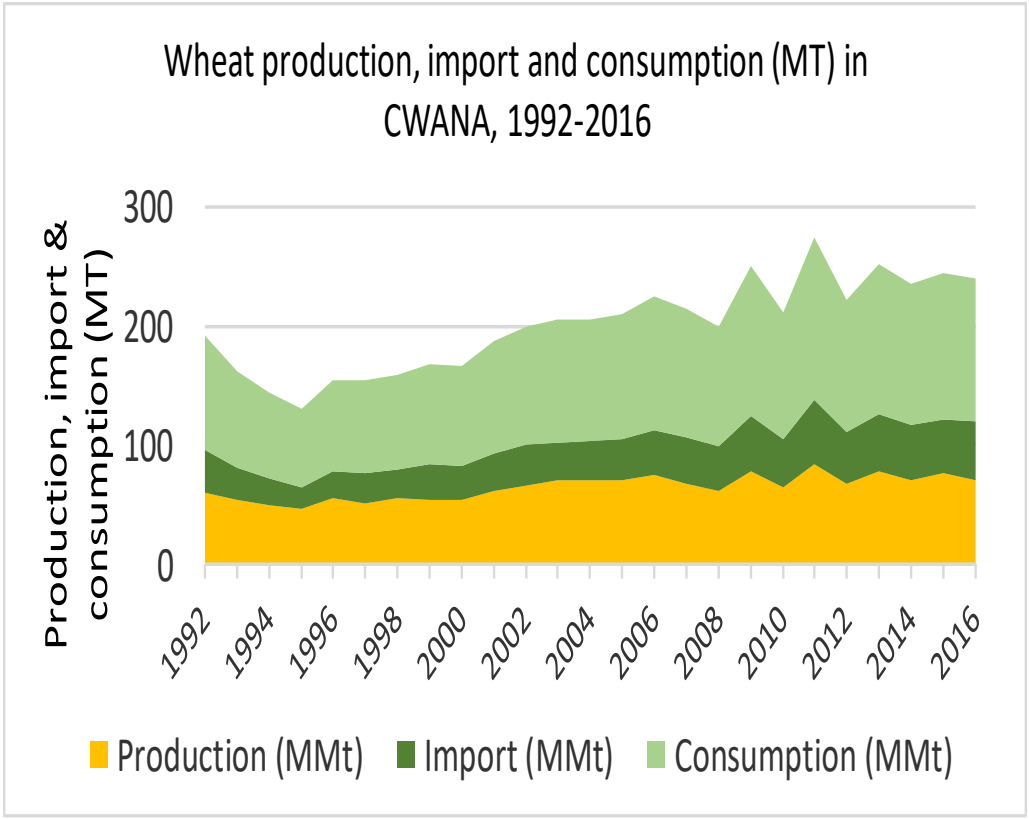
ICARDA

Science for resilient livelihoods in dry areas

Wheat in CWANA and SSA: Challenges & Opportunity

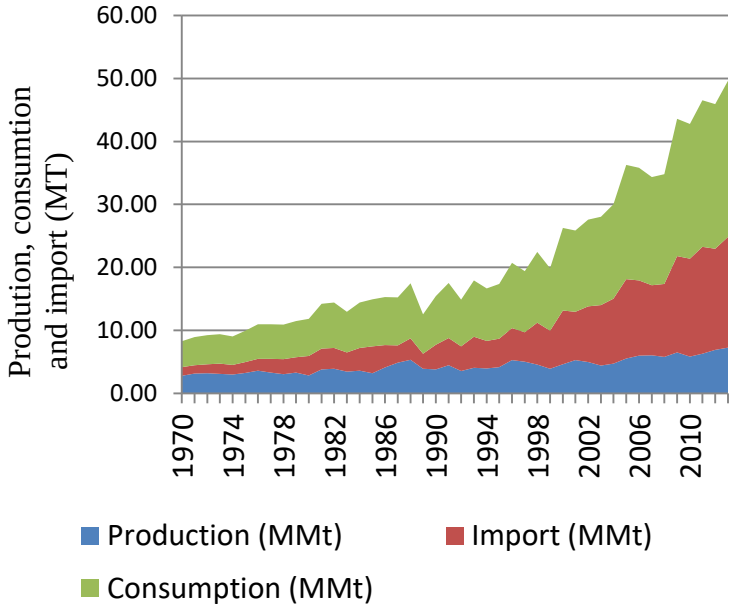
- Food security; stability of governance
- High per capita consumption (200kg/p/yr)
- Huge market potential (67 MT imort)

- Climate change
- Population growth
- Stability, infrastructure
- Abiotic and biotic stresses



2016: Consumption 120 MT; Import 50 MT

Wheat production, import & consumption (MT) in SSA, 1970-2016



2016: 17MT; 6B$

Major production constraints

* based on surveys and NARS priorities

Abiotic stresses

- Drought
- Heat
- Cold
- Salinity
- Pre-harvest sprouting
- Water lodging

Biotic stresses

- Yellow rust
- Stem rust
- Leaf rust
- Fusarium
- Septoria
- Tan spot
- Common bunt
- Root rots
- Hessian Fly
- Russian Wheat Aphid
- Sunn Pest

CCN

Strategies and approaches

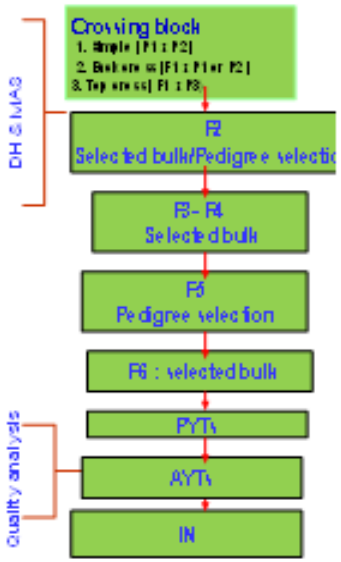
* Reviewed and approved in 2012

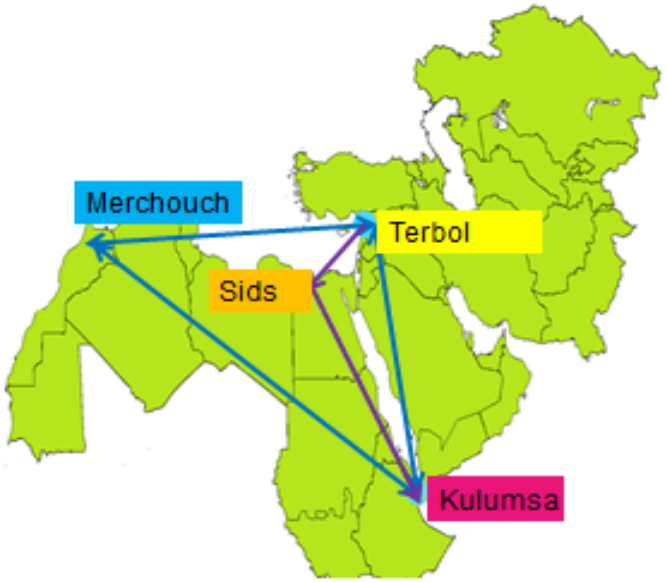
- Classification and targeting major MEs
- Shuttle breeding
- Marker assisted selection
- Use of wide crosses (Synthetics)
- Hot spots for disease screening
- Multi-location testing

Major Wheat Breeding Objecti

- High yield potential and broad adaptation
- Resistance to major diseases and insects
- **Drought, heat**, cold and salinity tolerance
- Grain quality
- Capacity building of NARS through training

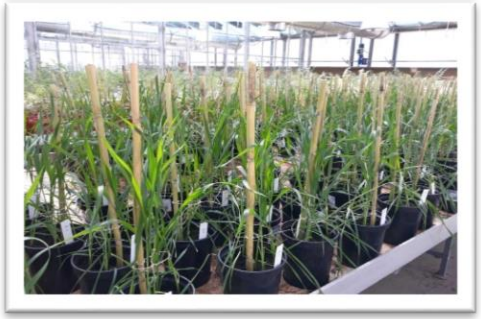
Breeding Methods and Germplasm Flow





Breeding methods for spring bread wheat- ICARDA

Year #	Doubled haploid	Classical 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 (700-1200) across key locations

Key Locations

Marchouch + Jemaat Shaim: Yellow rust, Septoria, drought tolerance, HF resistance

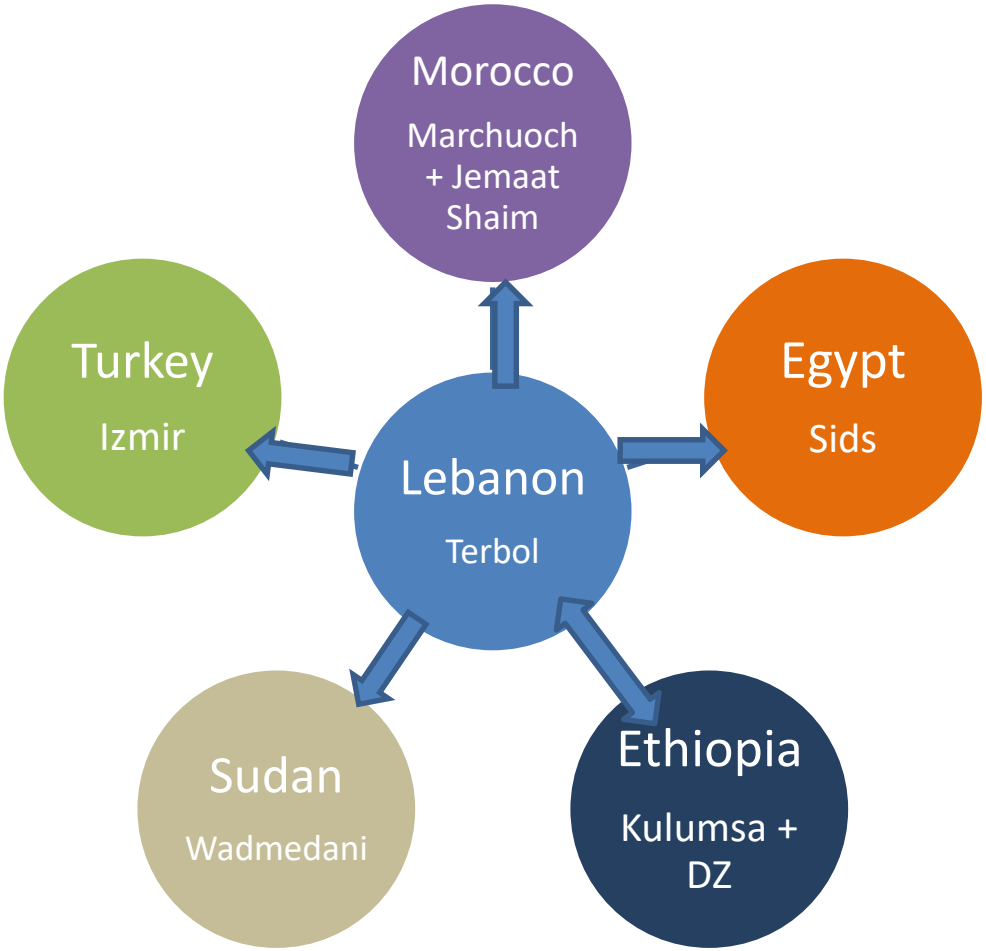
Sids: Yield potential

Izmir: Screening for rusts (Lab +field)

Kulumsa /Dz: Stem rust, yellow rust, septoria, fusarium

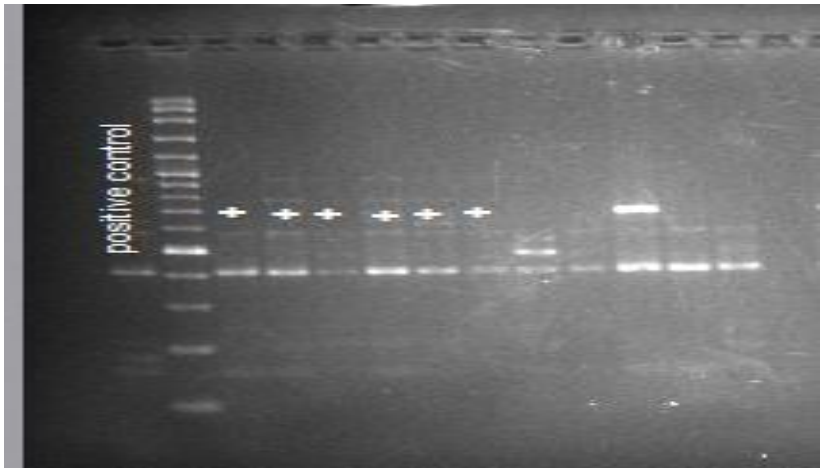
Wadmedani: Heat tolerance

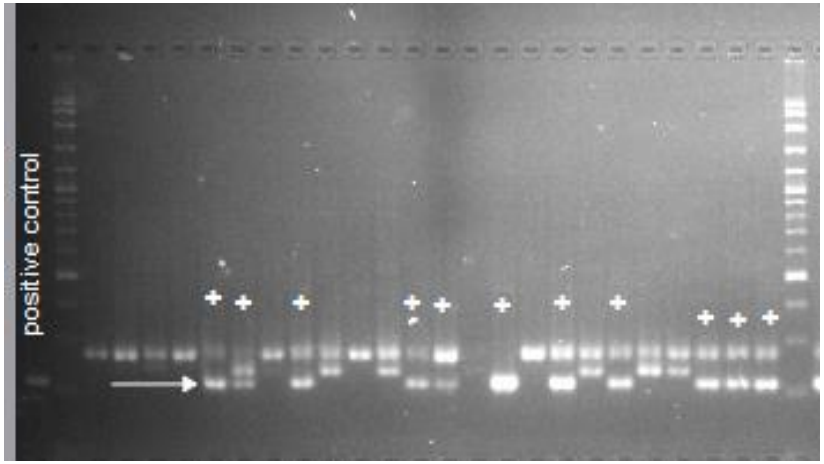
Terbol: CB, adaptation, yield potential, rusts, cold, drought (at Kheferdan)



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		

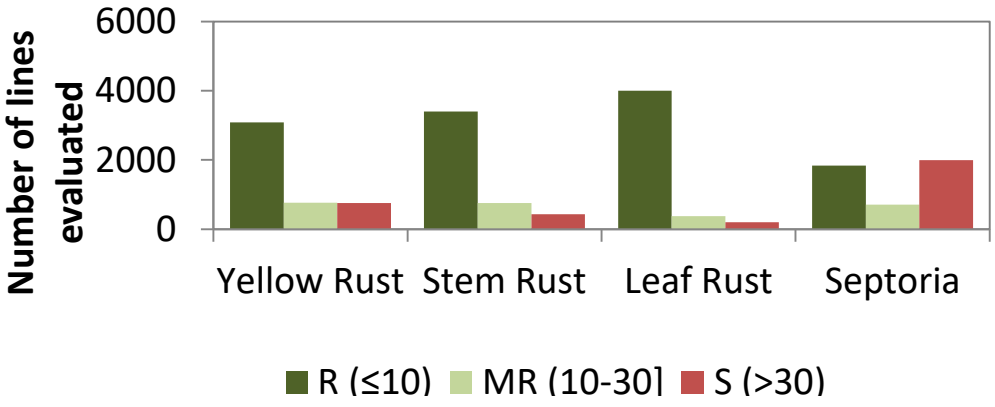


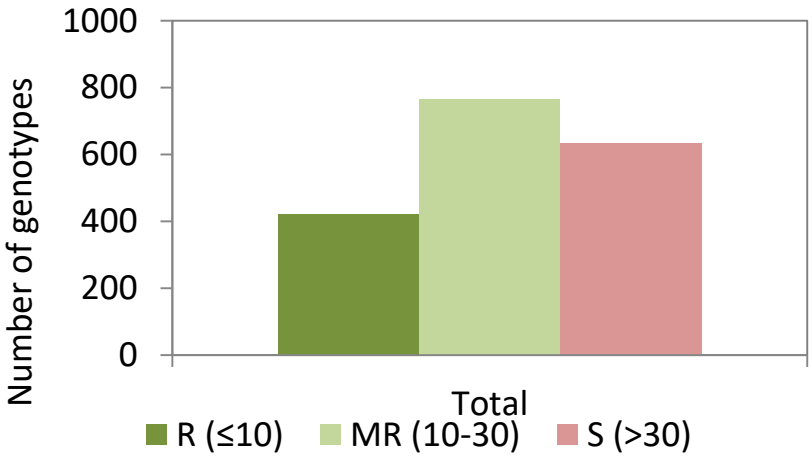


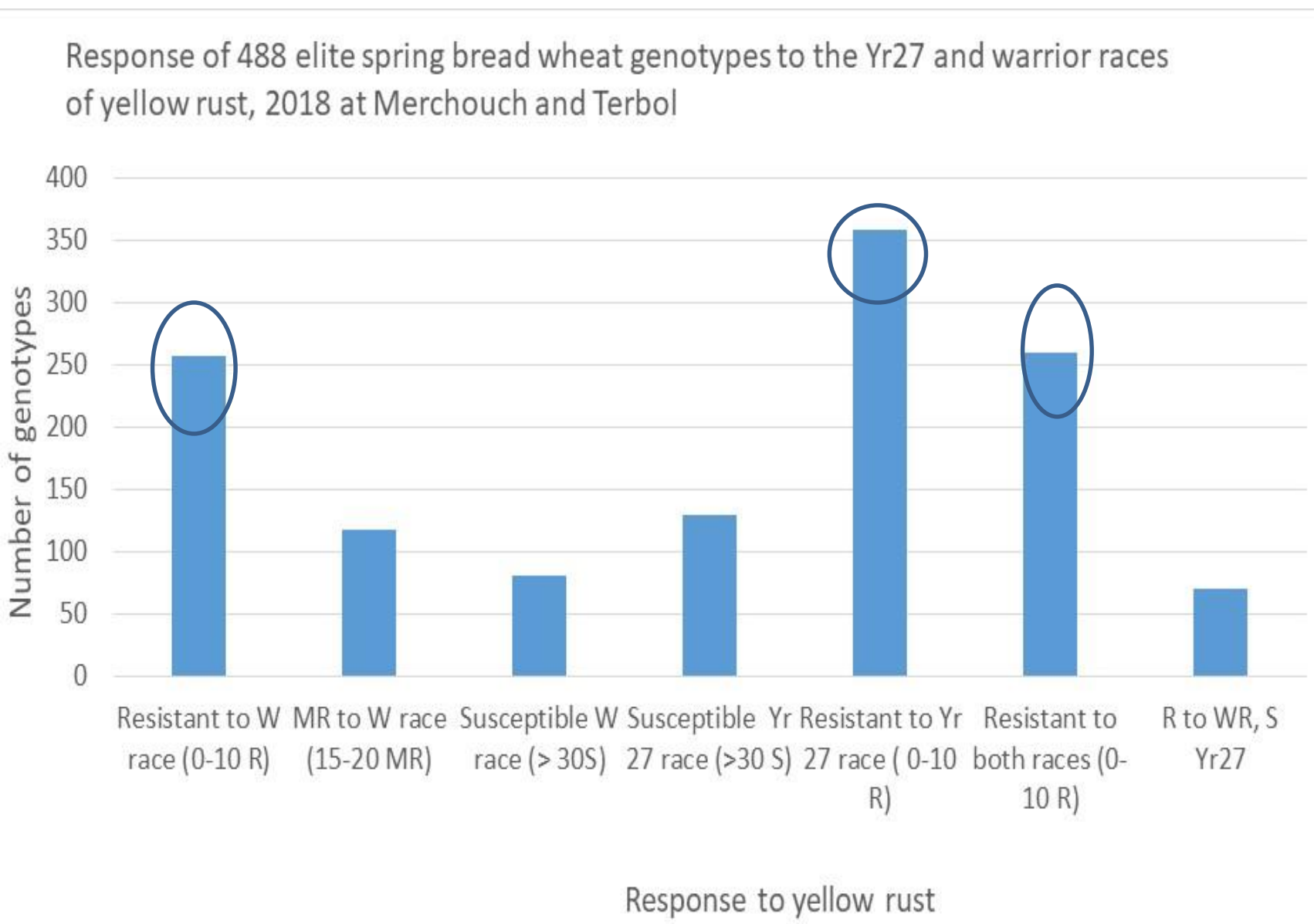
Genetic stocks from Dr Evans Lagudah

Resistance to Diseases

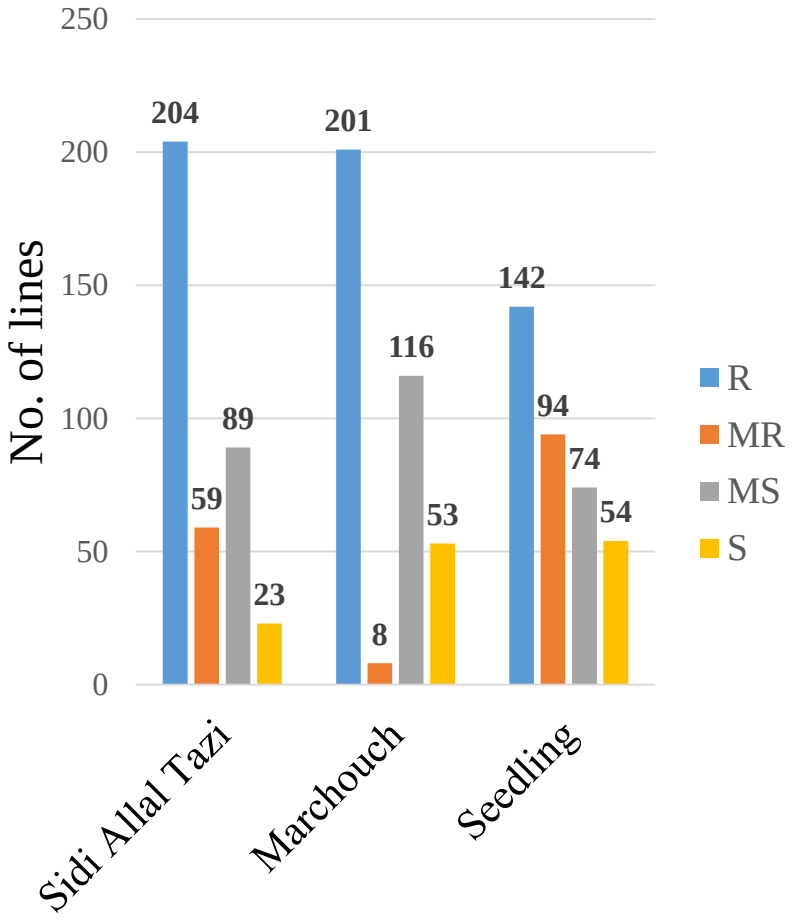
Response of 4600 ICARDA's spring bread wheat genotypes to rusts and septoria at Kulumsa (above) and at Merchouch (below)

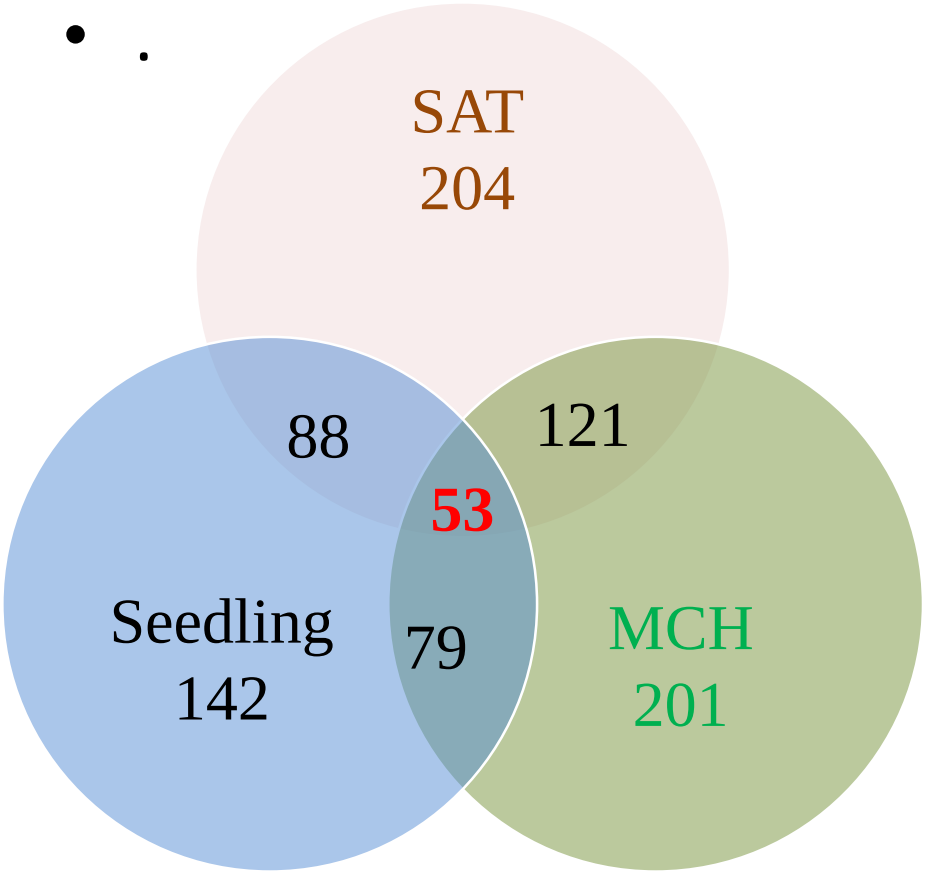





Response of 488 elite spring bread wheat genotypes to the Yr27 and warrior races of yellow rust, 2018 at Merchouch and Terbol
Number of genotypes
400
350
300
250
200
150
100
50
0
Resistant to W race (0-10 R)
MR to W race (15-20 MR)
Susceptible W race (> 30S)
Susceptible Yr 27 race (>30 S)
Resistant to Yr 27 race (0-10 R)
Resistant to both races (0-10 R)
R to WR, S Yr27
Response to yellow rust

Response of 377elite spring bread wheat genotypes to *Septoria tritici at* Marchouch, Sidi Allal Tazi with artificial inoculation (field) and Seedling screening under controlled conditions using mixture of 10- isolates





Synthetic derived wheat genotypes and their performance
* DH population for HF and Sun pest combined resistance

Name	Days to heading	Plant height (cm)	Yelow rust severity	1000 seed weight (gm0	Yield (t/ha)
NEJMAH-11	108	90	10MR	44	8.2
NEJMAH-8	108	85	10MR	43	7.4
NEJMAH-12	108	85	15MR	45	7.1
TAJ-1	107	100	40S	42	7.1
SHIHAB-8	109	95	5R	50	7.1
NEJMAH-19	109	85	10MR	45	6.9
MUNIA//CHEN/ALTAR 84/3/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN	103	100	5R	46	6.7
SHIHAB-4	109	100	5R	55	6.7
SHIHAB-20	109	90	10MR	43	6.7
NEJMAH-17	108	90	5R	42	6.6
NEJMAH-20	108	90	10MR	44	6.6
NEJMAH-21	107	100	10MR	42	6.6
BEDER-5	107	90	10MR	39	6.6
SHIHAB-13	108	100	20MS	48	6.4
SHIHAB-19	108	100	5R	46	6.3
NEJMAH-6	108	85	5R	44	6.3
CROC-1/AE.SQUARROSA (205)//KAUZ/3/SASIA	107	85	5R	41	6.1
SHAMIEKH-1	110	95	5R	44	6.1
NEJMAH-26	108	90	5R	45	6.1
NEJMAH-18	114	90	5R	47	6.1
QAMAR-4	107	95	5R	39	6.0
Attila-7 (check)	108	95	5R	38	4.8

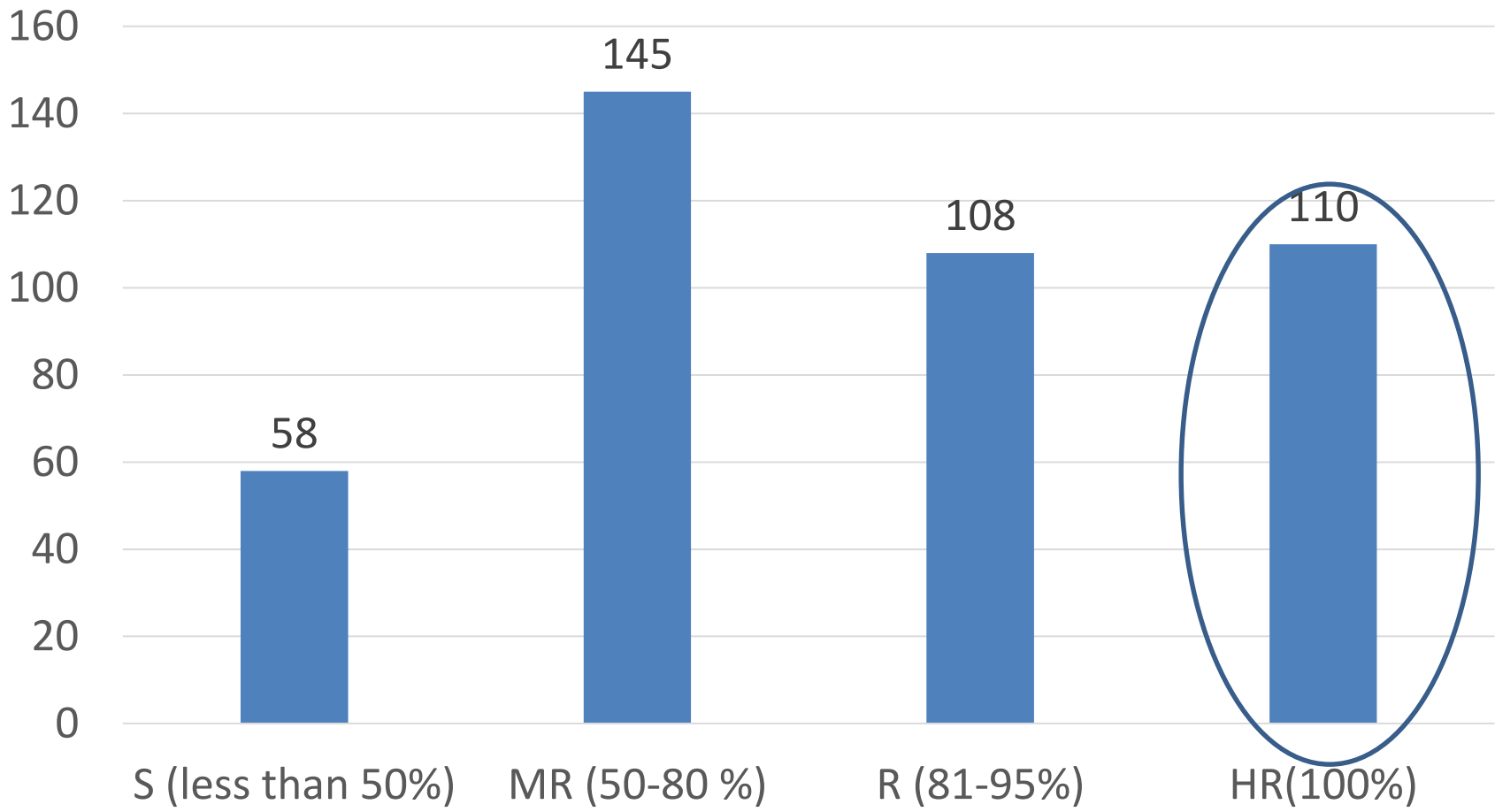
Resistant to both HF and SP

TRN/AE.SQUARROSA (700)

GAN/AE.SQUARROSA (248)

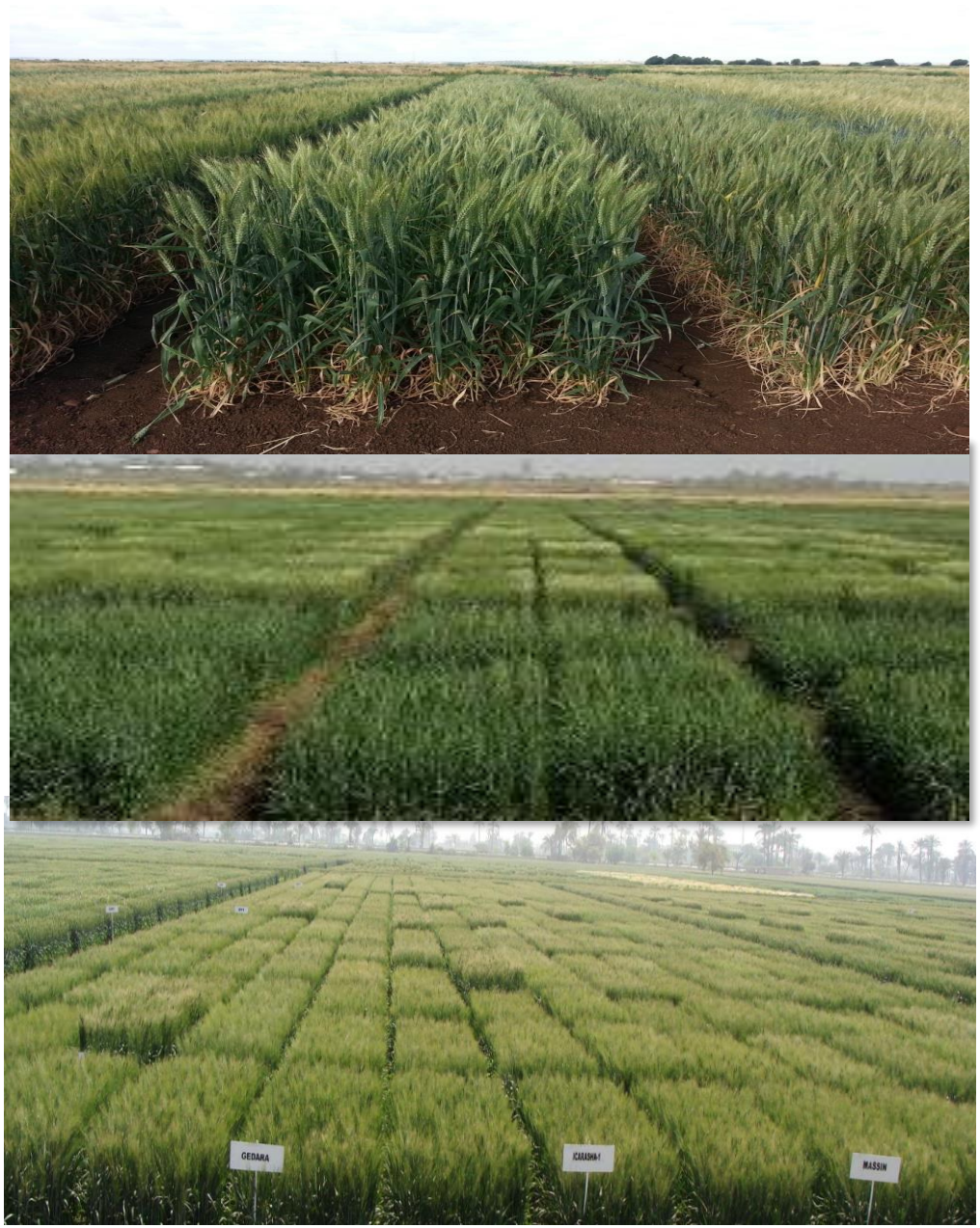
68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (1038)

Response of high yielding, yellow rust resistant, and drought tolerant elite spring bread wheat genotypes to HF, 2018

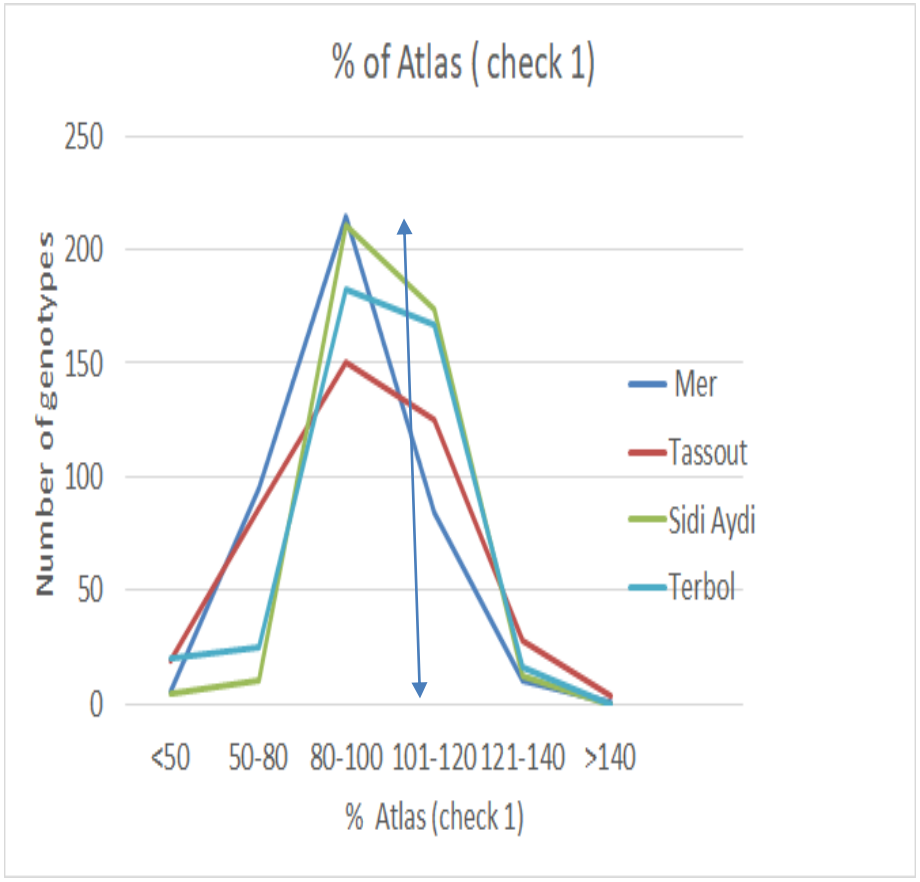


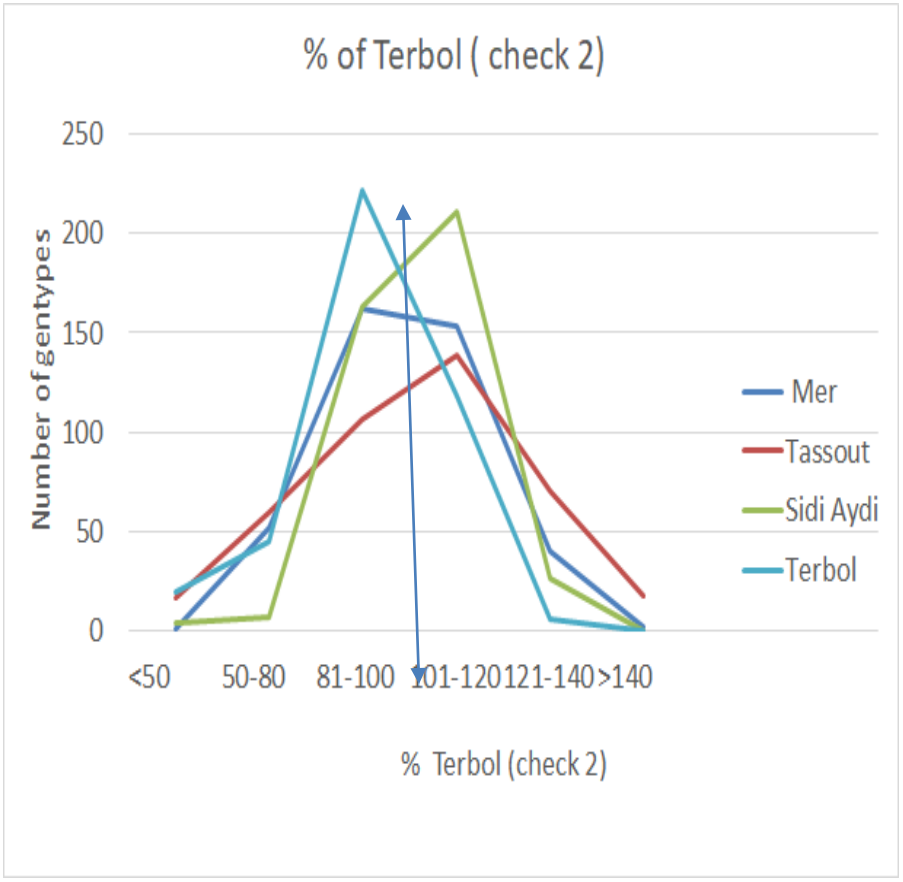
Yield (t/ha) of selected elite wheat genotypes across key locations, 2018

Pedigree	MR	WM	SD
HUBARA-1/5/KAUZ/3/MYNA/VUL//BUC/FLK/4/MILAN	5.5	2	8.1
HUBARA-5/3/NESMA*2/261-9//FIRETAIL	5.1	3.8	9.8
WHEATEAR//ACHTAR/INRA 1764	4.8	5.1	8.4
CHAM-8/RUTH-3	4.7	4.2	9.3
MO88/MILAN//ETBW 4922/3/(4) EALME4SA - 464	4.7	4.2	8.9
22SAWSN - 142/ETBW 4921/6/HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	4.7	2.3	8.4
HUBARA-5//PFAU/MILAN	4.7	3.1	8.4
DAJAJ-5/4/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/KAUZ/5/WBLL1*2/KIRITATI	4.5	3.7	9.3
TRAP#1/BOW//PFAU/3/MILAN/4/ETBW 4922/5/PFAU/MILAN	4.4	3.3	9.2
SERI.1B//KAUZ/HEVO/3/AMAD/4/ESWYT99#18/ARRIHANE	4.4	3.3	9
ASEEL-1//MILAN/PASTOR/3/SHAMISS-3	4.2	4.2	9.4
DAJAJ-5/4/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/KAUZ/5/WBLL1*2/KIRITATI	4.1	4.3	9.8
DEBEIRA//SHUHA-8/DUCULA/3/PASTOR/SERI//PFAU	4.1	4.8	9.3
ASEEL-1//MILAN/PASTOR/3/SHAMISS-3	4.1	3.6	12
GEMMEIZA-10/SHAMISS-3	4.1	2.9	10
DAJAJ-5/4/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/KAUZ/5/WBLL1*2/KIRITATI	4	4.1	9.1
DEBEIRA//SHUHA-8/DUCULA/3/PASTOR/SERI//PFAU	3.4	3.5	10.1
Imam	3.5	3.9	8.1
Misir 2	3.4	3.4	9
Terbol	3.5	3.6	8.4

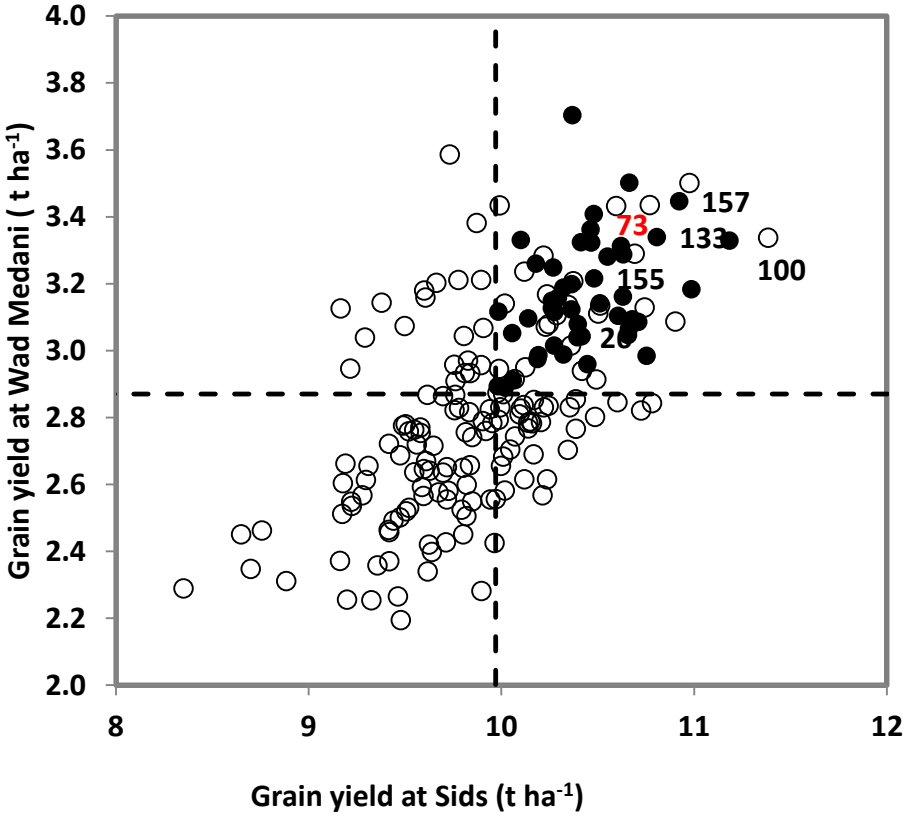


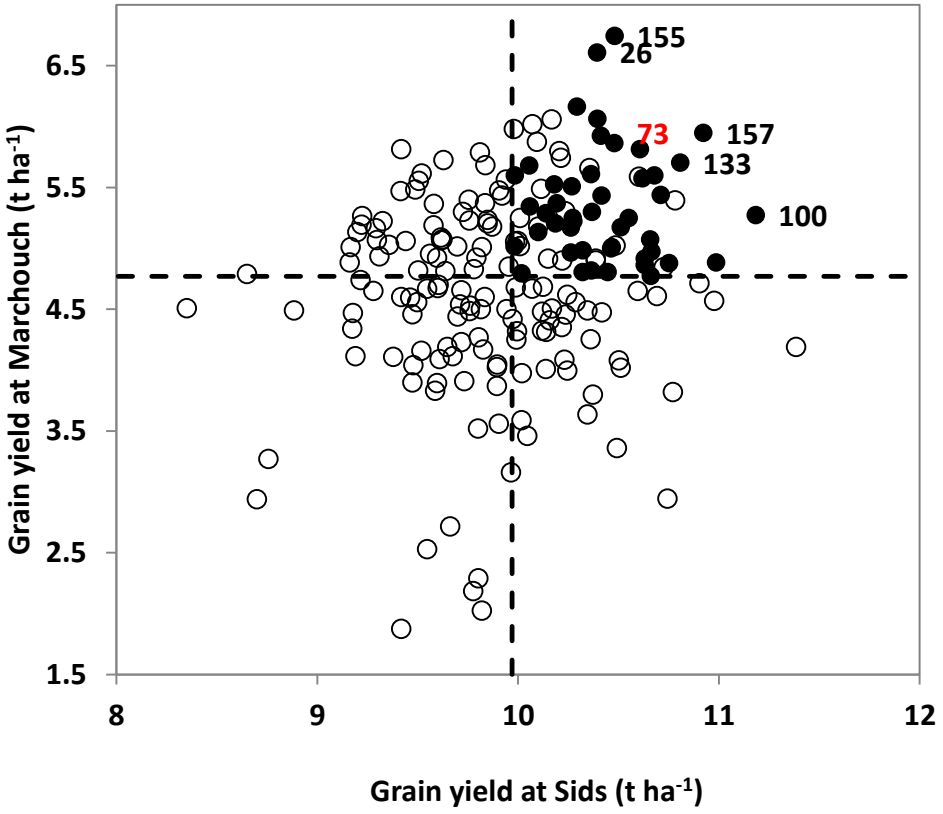
Performance of elite spring bread wheat genotypes in % of Atlas (check 1) and Terbol (check 2) across locations, 2018





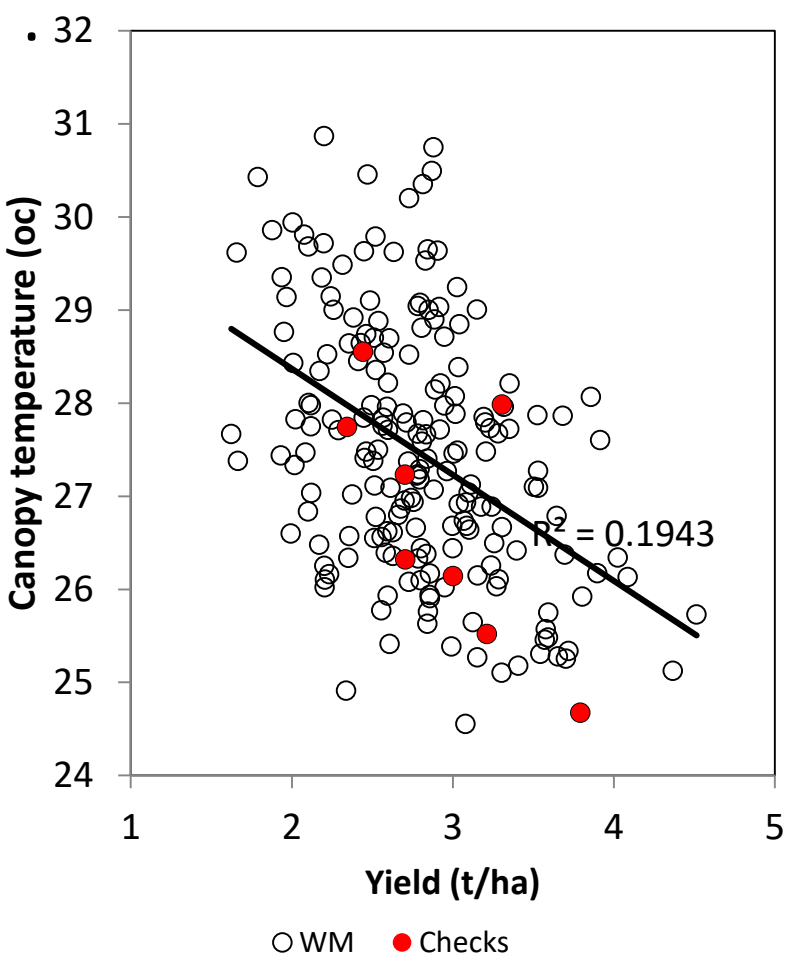
Yield of wheat genotypes across key locations

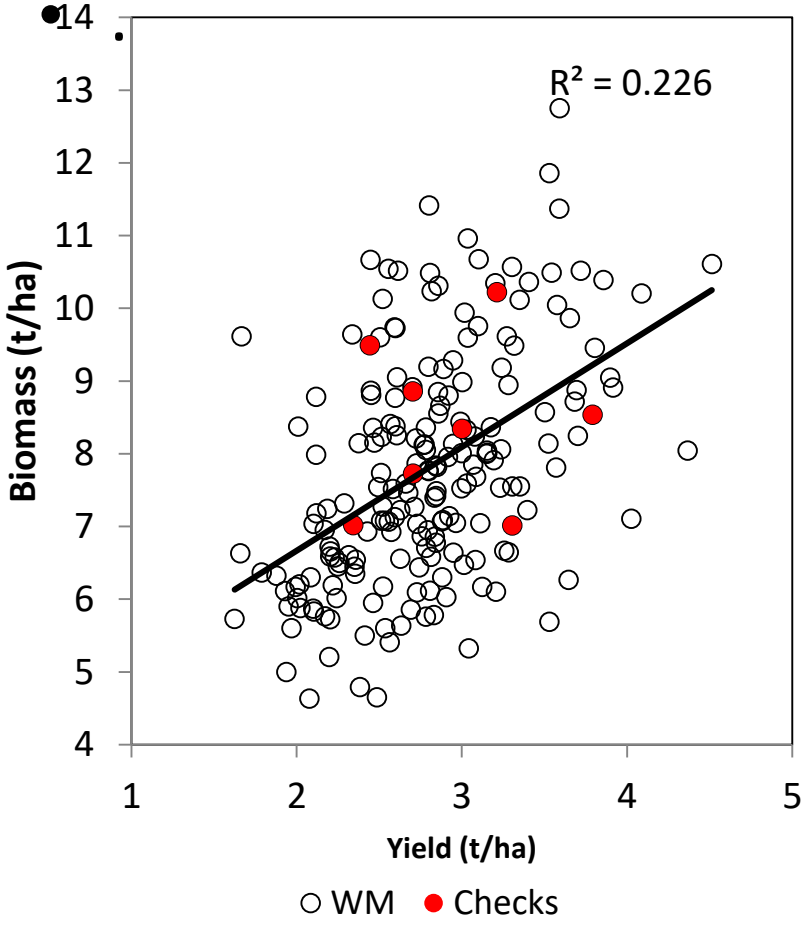




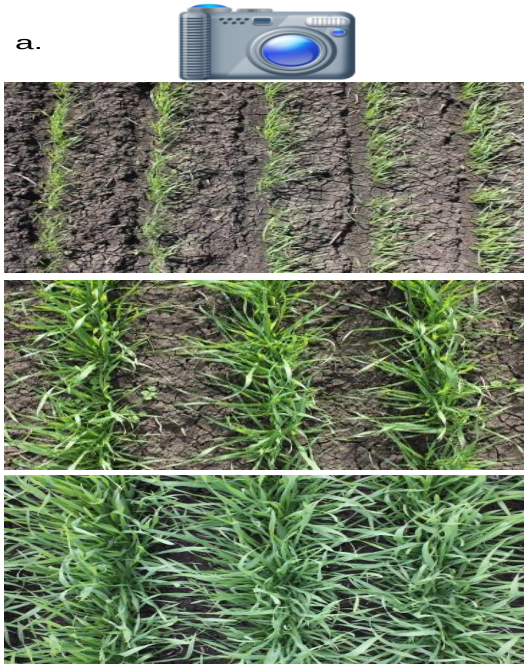
● Above average in SIDS, WM and Marchouch

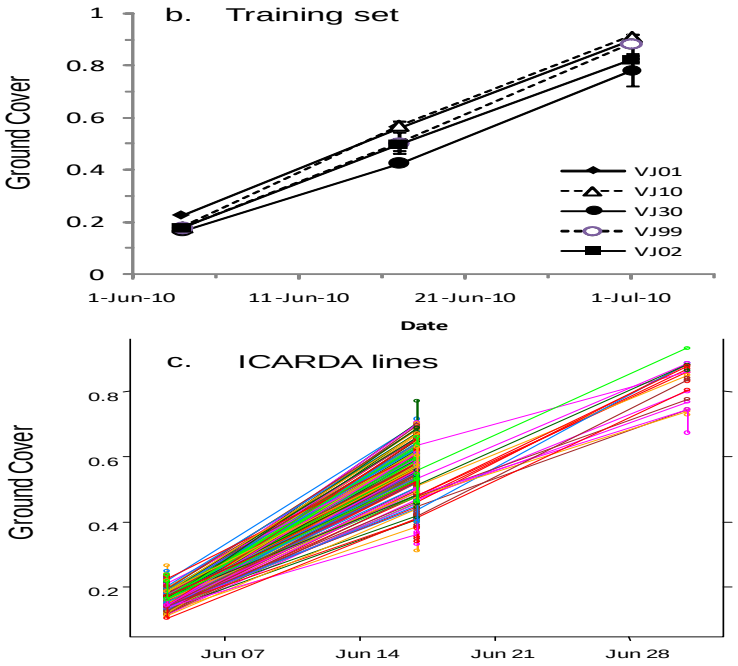
Association among key traits





Variation in early ground cover

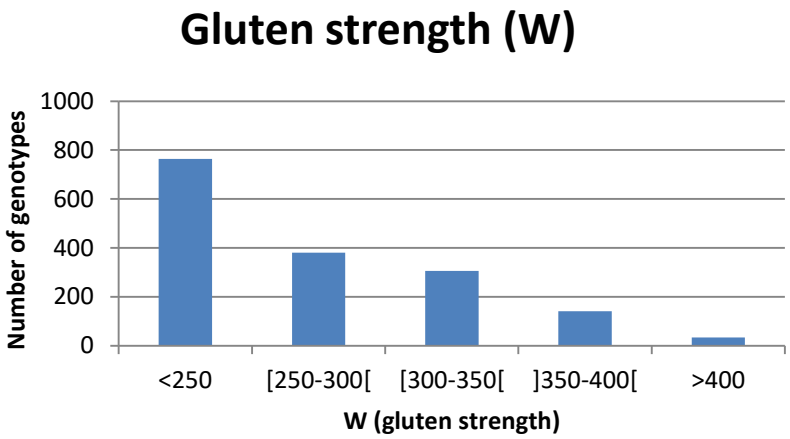


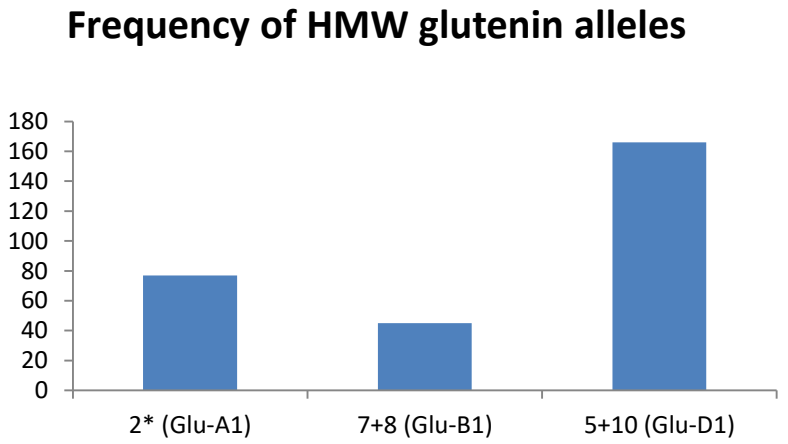


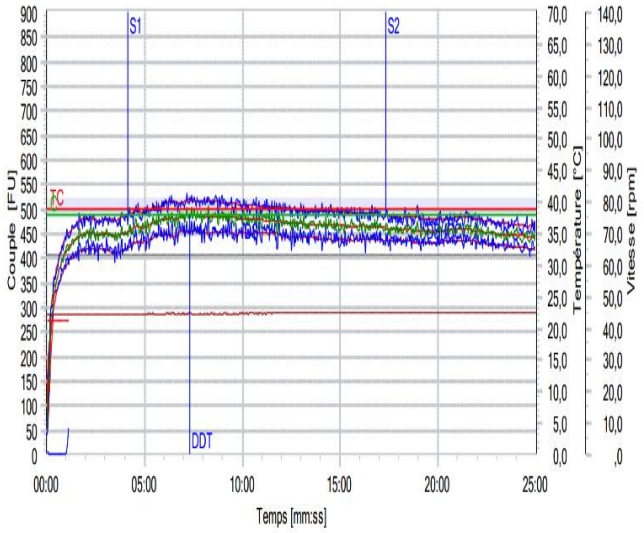
Dreccer et al. 2014

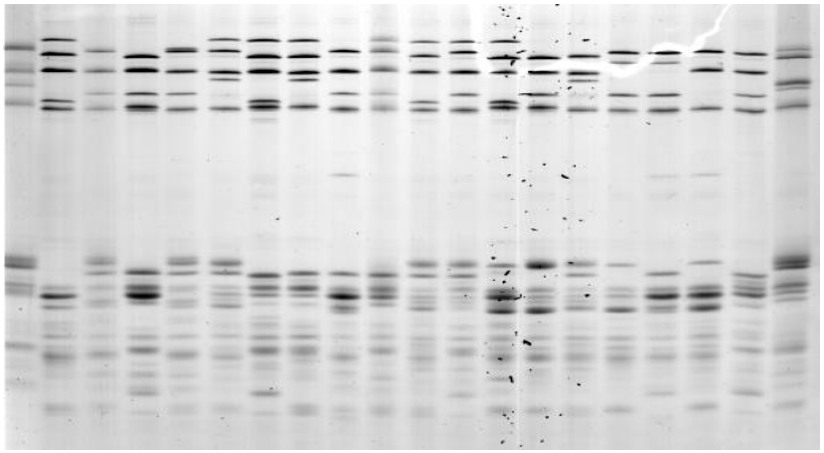
Pedigree analysis : synthetic hexaploid wheats (SHWs) ; *T. dicoccoides* in their background.

Variability of elite wheat genotypes for gluten strength (W), and HMM glutenin alleles at Merchouch



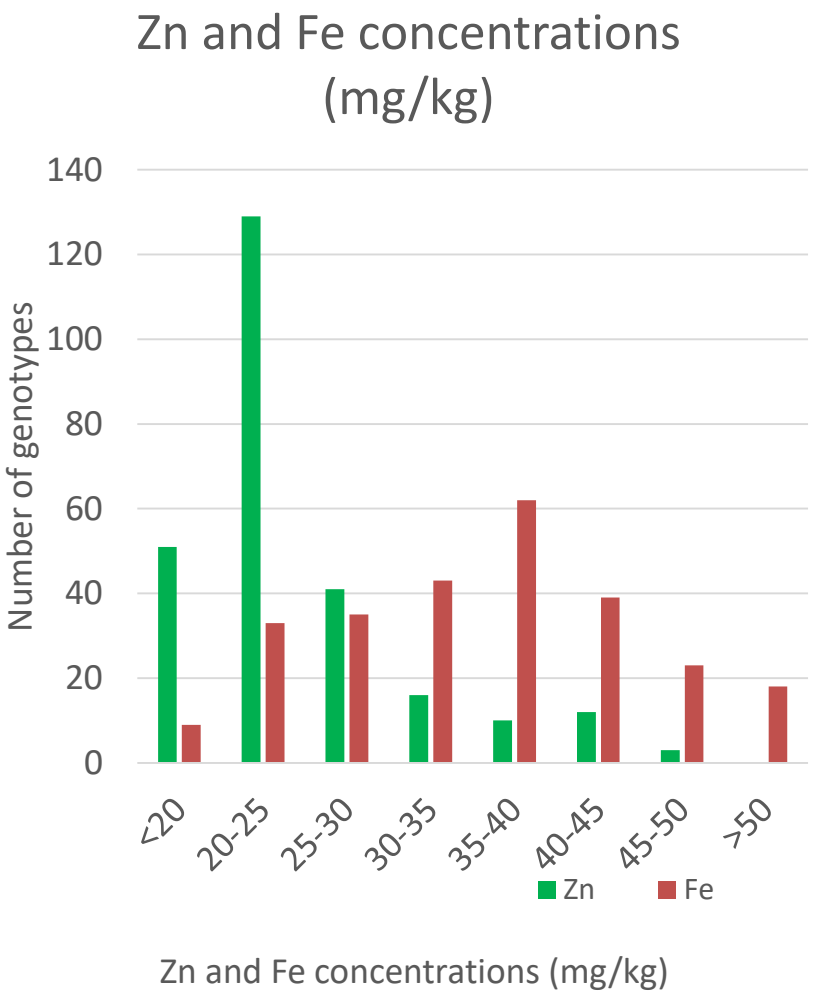






High yielding wheat genotypes with high concentrations of Zn, Fe and Se

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
28243	TRAP#1/BOW//PFAU/3/MILAN/4/ACHTAR/INRA 1764/5/MILAN/SHA7/3/THB/CEP7780//SHA4/LIRA/4/SHA4/CHIL	38.90	41.807	0.363
28406	ESDA/SHWA//BCN/3/MILAN/PASTOR	37.35	48.514	0.252
29117	SIDS-1//ATTILA*2/RAYON	36.66	55.863	0.267
29182	ESDA/SHWA//BCN/3/MILAN/PASTOR	35.51	50.033	0.216
29221	AMIRA-2//CHAM-6/SHUHA-14/3/SAMIRA-9	33.81	45.699	0.366
29232	VEE/PJN//2*KAUZ/3/SHUHA-4/FOW-2	33.40	26.623	0.227
29272	GOUMRIA-15/ANGI-1//MILAN/MUNIA	32.74	53.837	0.384
29298	CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/KAUZ/4/DAJAJ-8	32.10	54.611	0.390
29334	CHAMRAN/4/OPATA/BOW//BAU/3/OPATA/BOW/5/SAMIRA-9	31.47	50.058	0.362



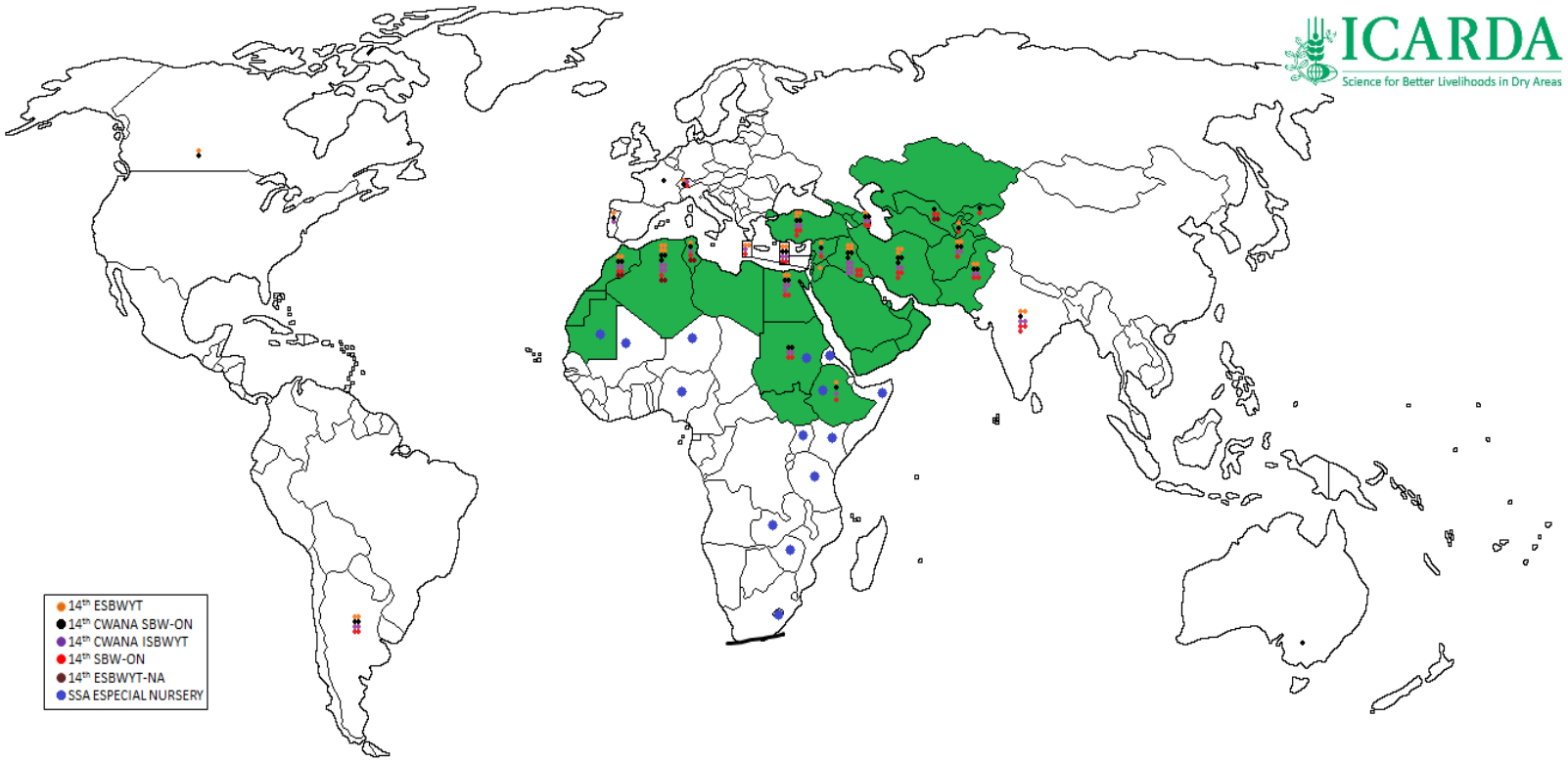
Distribution of International Nurseries and Yield Trials

The following International nurseries and yield trials have been distributed from Terbol station, Lebanon to more than 30 countries in the CWANA and SSA regions and beyond up on request from the NARS .

1. Spring bread wheat observation nursery for CWANA (CWANA SBWON)
2. Spring bread wheat observation nursery for heat tolerance (HT-SBWON)
3. Spring bread wheat yield trial for HT(ESBWYT-HT)
4. Spring bread wheat yield trial for dry-land environments (CWANA DSBWYT)
5. Elite spring bread wheat yield trial (ESBWYT)
6. Especial nursery for 12 countries in Sub Saharan Africa (AfDB project)

*www.**icarda**.org/research-sub/**international nurseries***

Geographic distribution of ICARDA' s spring bread wheat international nurseries



In the last 5 years more than 60 wheat varieties of ICARDA origin have been released by the national programs in the CWANA and SSA regions. Some of them are with synthetic backgrounds in their pedigree.

SARD-SC/ TAAT
wheat technology out-scaling

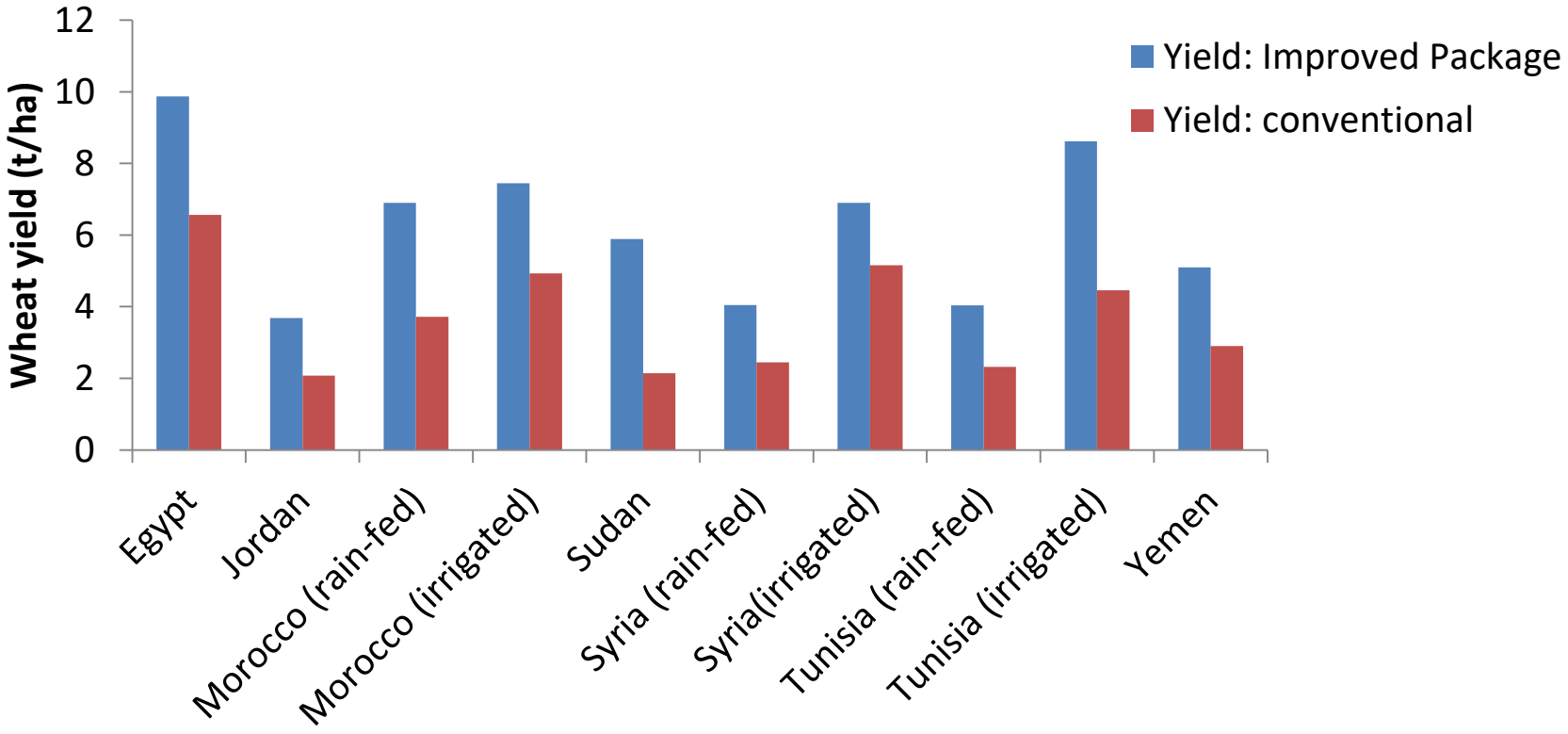
Target: 12 countries

- 3 hub and 9 partner countries, Agro-ecologies: 2 main types
- Heat prone (lowlands)
- Disease prone (highlands)

- New varieties show 4-7t/ha instead of 1-2 t/ha
- Resulted in vertical and horizontal increase of wheat production in Nigeria, Sudan, Ethiopia

Source: SARD –SC/TAAT project

Grain yield of wheat under improved and conventional practices in selected countries, 2011-2018



Yield increase of 25-78% reported

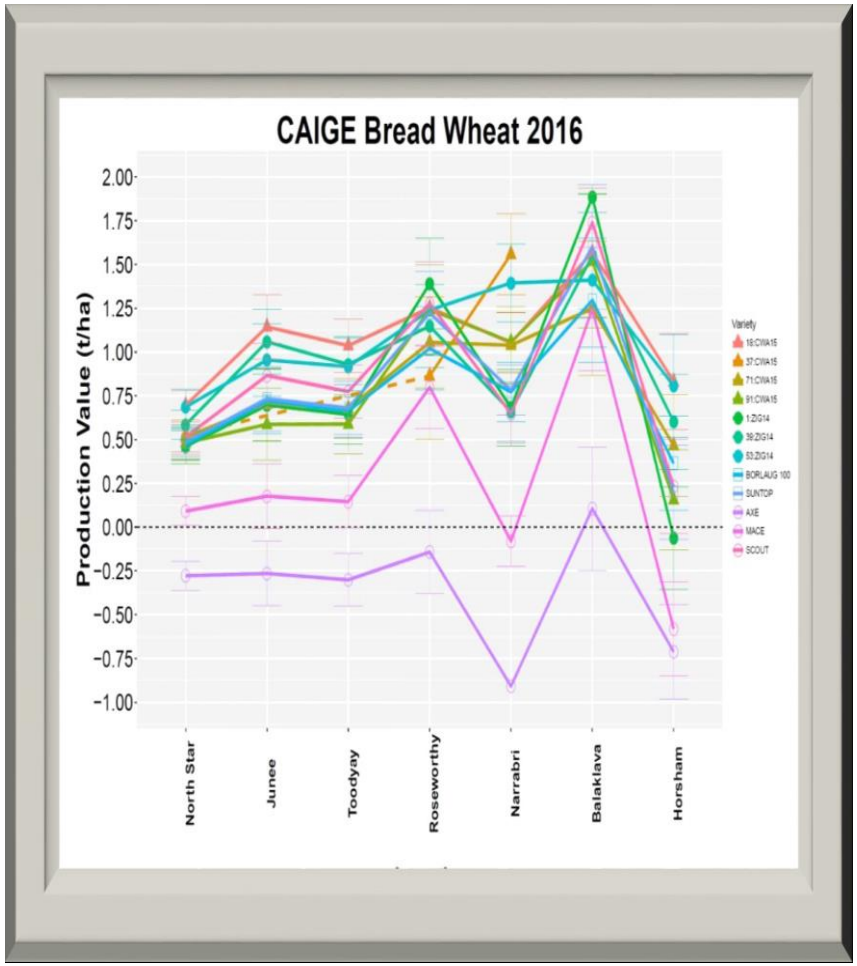
Source: Food security project in the MENA; Tadesse et al 2017

PVS, demonstration under CA, and linkage across the value chain in Morocco

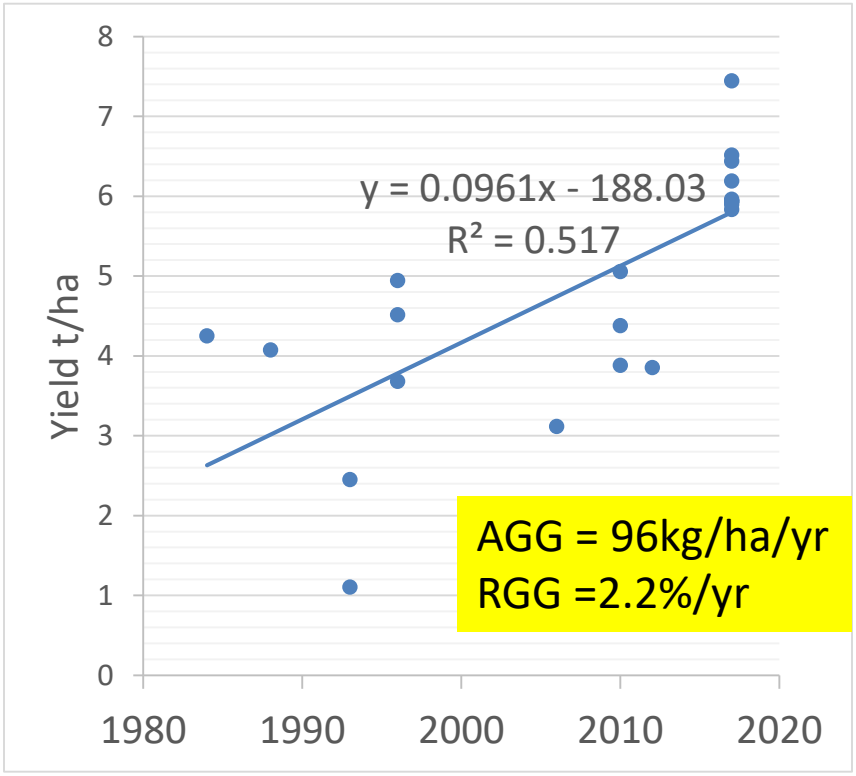
CAIGE: Best model for effective germplasm testing and utilization

Richard Trethowan, University of Sydney
Australian wheat breeders
GRDC

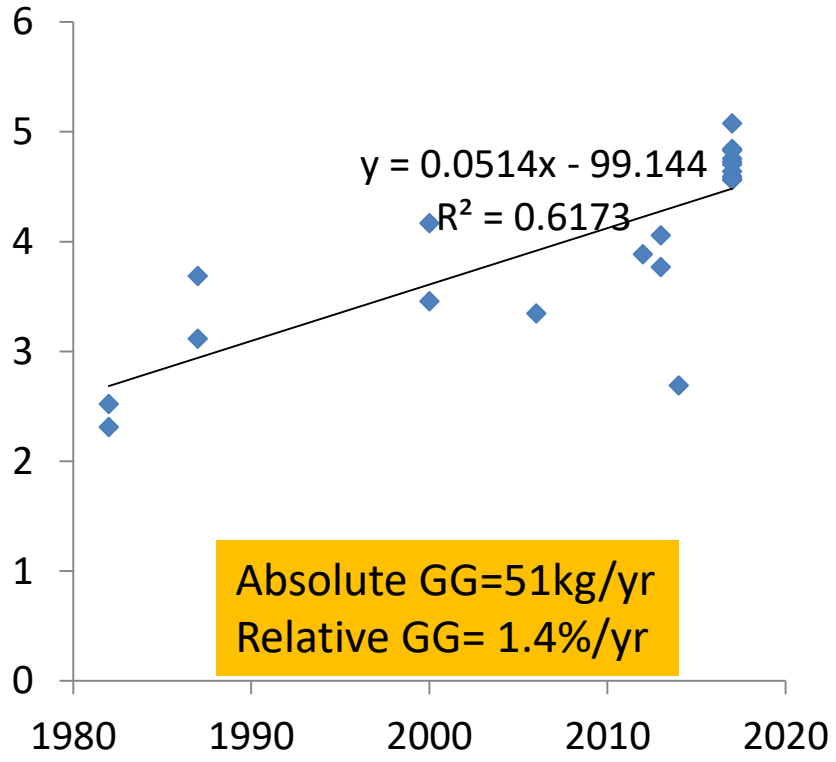
CAIGE 2016, 2017 (www.**caigeproject**.org.au)



Genetic gain for yield of spring bread wheat under moisture stress (Morocco) and heat stress in Wadmadani, Sudan, 2017-2018



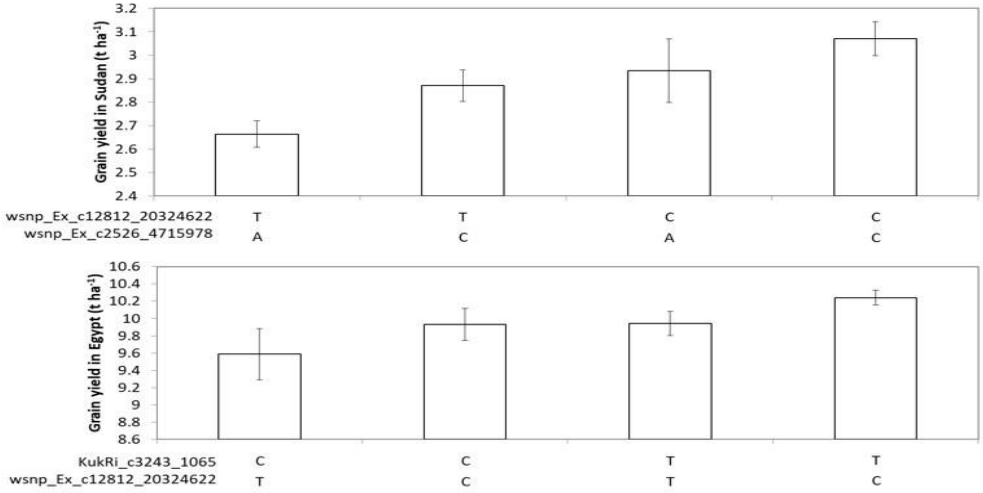
Merchouch, Morocco

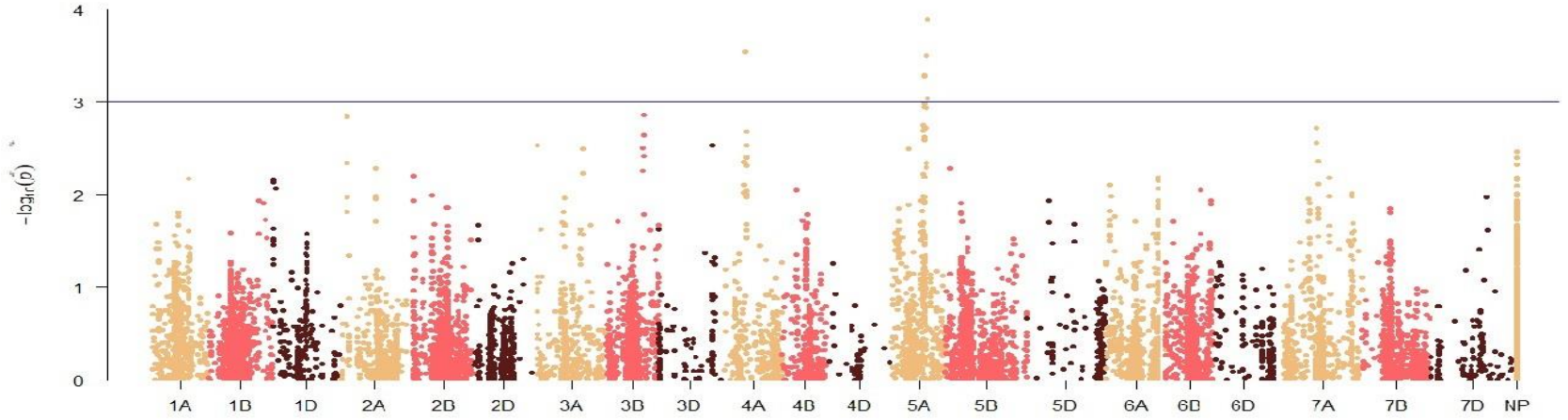


Wadmedani, Sudan

Tadesse et al 2019, Crop breeding and genomics

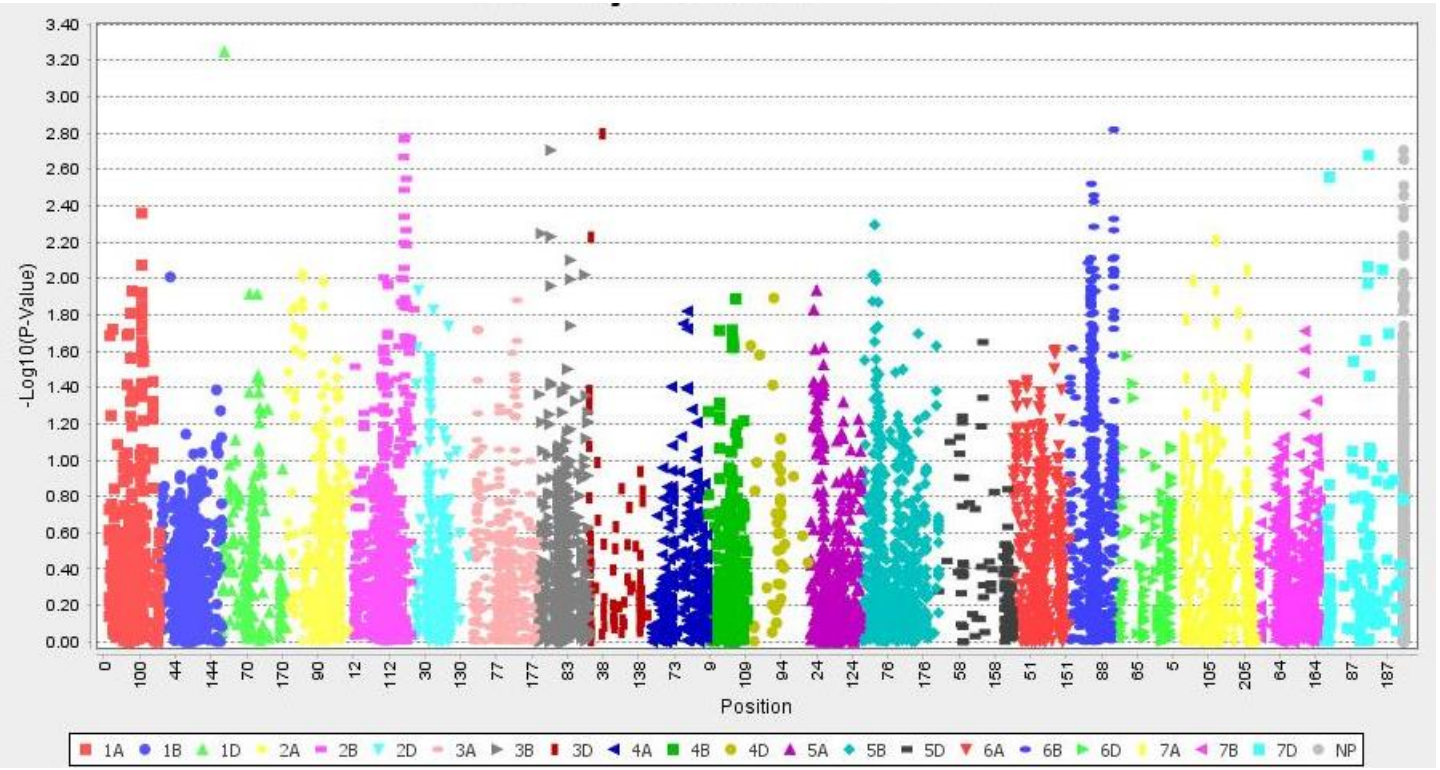
Significant marker alleles (on chromosomes 4A & 5A) and their contribution to yield under heat stressed environments





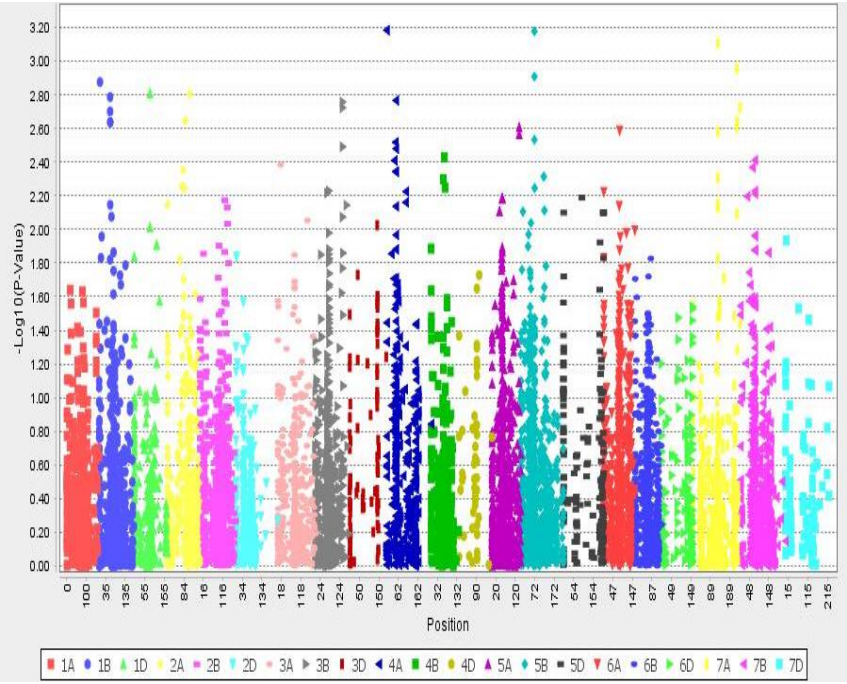
Tadesse et al. 2019, Crop Science

Drought tolerance

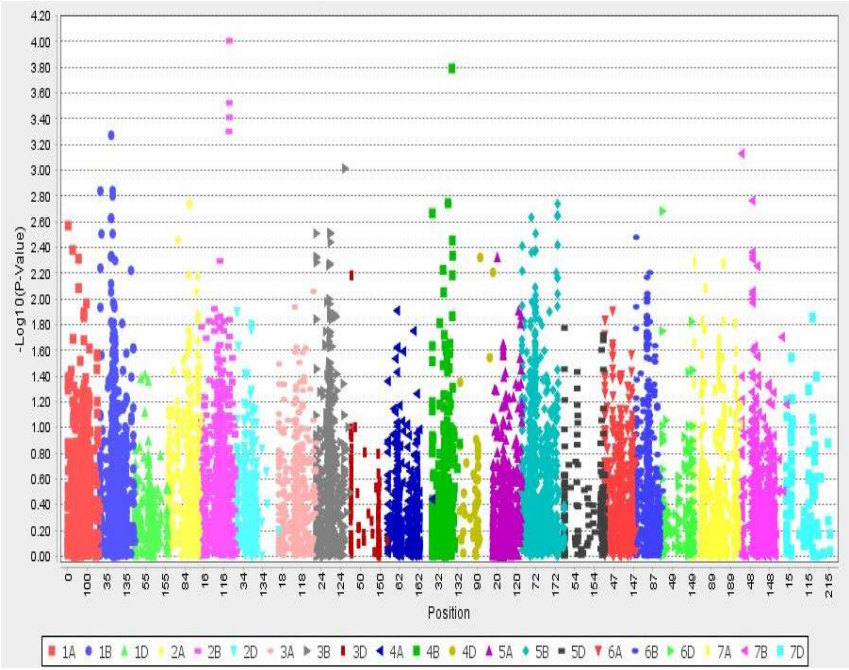


QTLs on 1D, 2B, 3B, 5B, 6B, 7A, 7D are correlated significantly with yield at Setttat, Morocco (Semi- arid environnent)

QTLs on 1B, 2B, 3B, 4B,5B,7B were significant with resistance to septoria both at adult plant (field) and seedling (greenhouse) stages

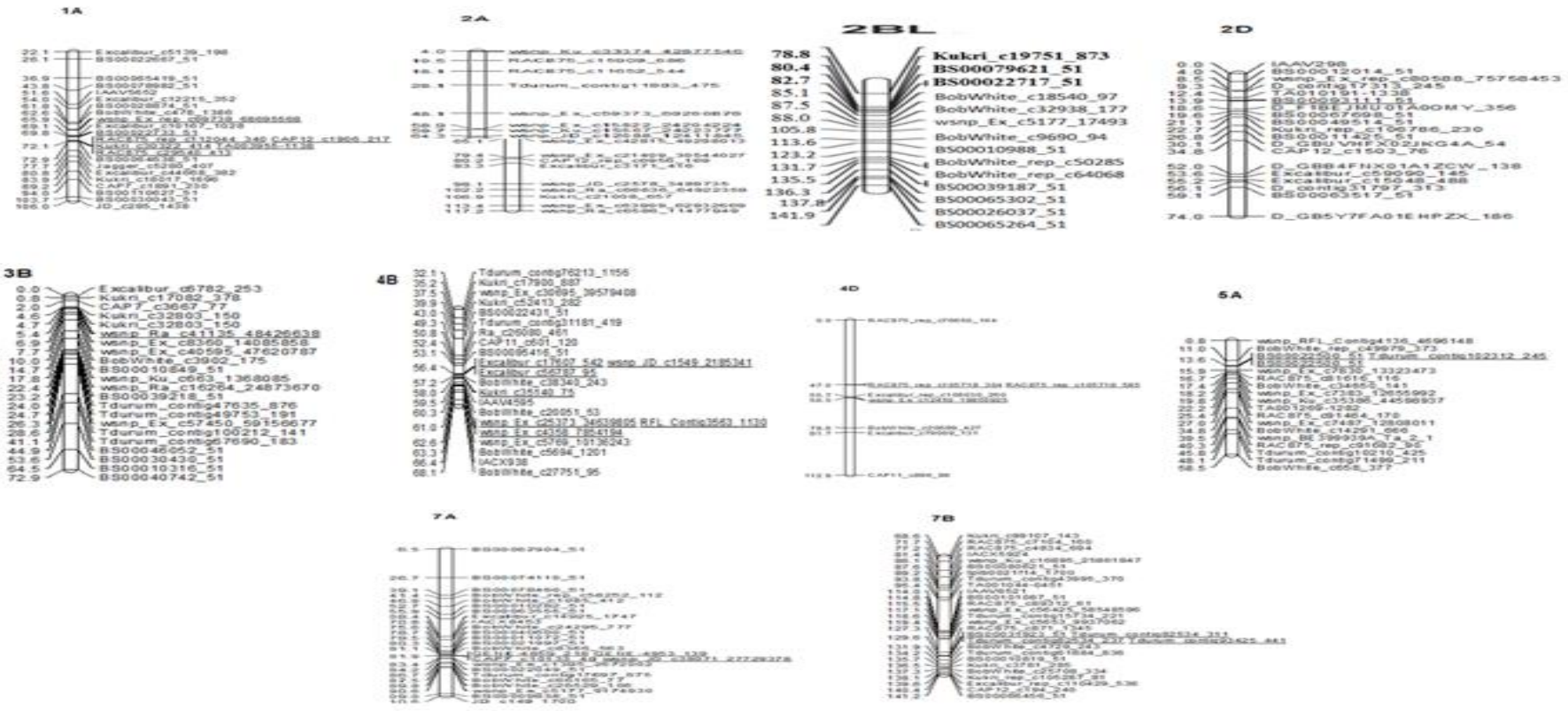


Adult plant resistance



Seedling resistance

Resistant QTLs identified against the warrior race of yellow rust in wheat (Yewbdar & Tadesse, 2018)



Determining the effective rate of CROISOR® 100 at Merchouch, Morocco

- 

…in partnership with Dr Baenziger, UNL

Successful gapping using CHA application at 13l/ha.

F1 Hybrid Performance & mid parents and the best parent heterosis

Entries-TRT	F1-Yield (t/ha)	Yield male (t/ha)	Yield female (t/ha)	%Heterosis over mid parents	%Heterosis over the best parent
18	4.88	3.74	3.76	30.30	29.97
12	4.54	4.01	3.12	27.23	27.23
4	4.74	3.82	3.69	26.23	26.23
10	5.09	4.01	4.34	21.91	17.27
5	5.13	3.82	5.02	20.71	2.23
9	4.73	4.35	3.69	17.76	17.76
42	4.76	3.88	4.83	17.72	-1.33
23	5.28	3.88	5.02	16.58	5.14
20	4.93	4.75	3.76	15.88	15.88
1	5.11	3.82	5.02	15.64	1.85
11	4.75	4.01	4.35	13.45	9.01
2	4.90	3.82	4.83	13.25	1.47
7	5.17	4.35	4.83	12.56	7.00
22	4.64	3.88	4.69	12.26	-1.07
3	4.78	3.82	4.69	12.21	1.86
19	5.00	4.75	4.34	10.26	10.26
16	4.26	3.74	4.34	9.75	-1.89
15	4.46	3.82	4.34	9.43	2.67
17	4.34	3.74	4.20	9.39	3.41
8	4.91	4.35	4.69	8.65	4.74
21	3.97	3.88	3.69	5.00	5.00
6	4.88	4.35	5.02	4.23	-2.83
14	3.94	3.82	3.76	4.01	4.01
13	3.89	4.01	3.95	-2.32	-2.32

Heterosis over mid parent (H%)

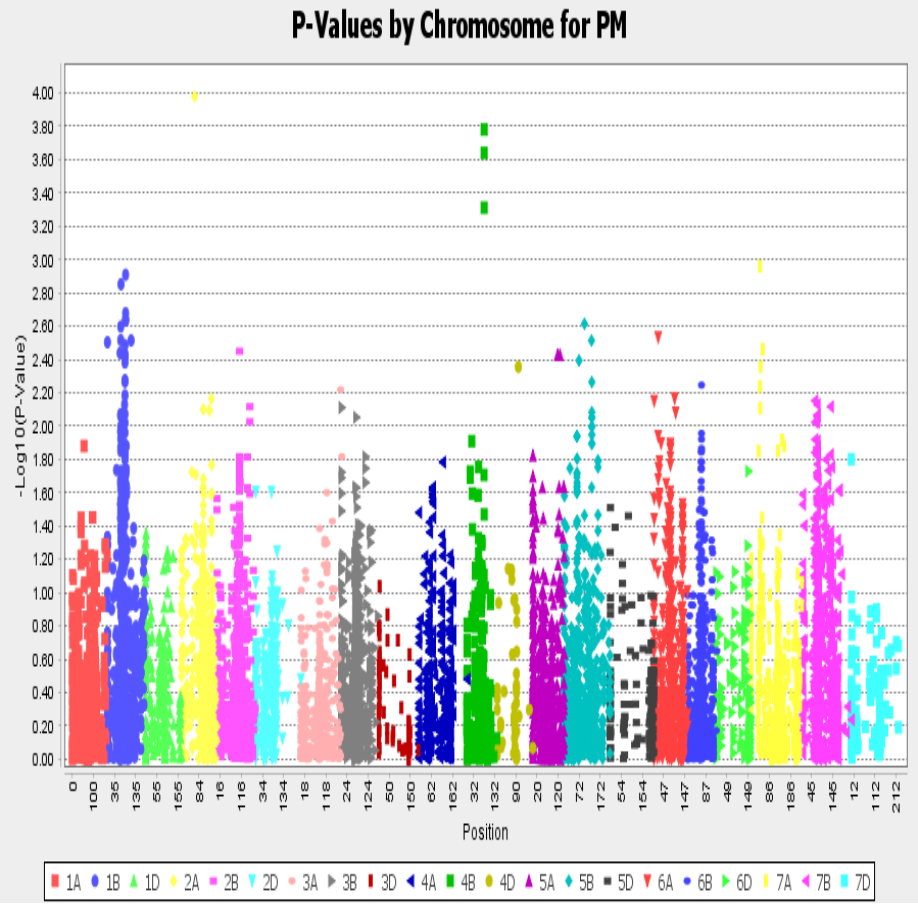
$=[(F1-MP)/MP\times100]$

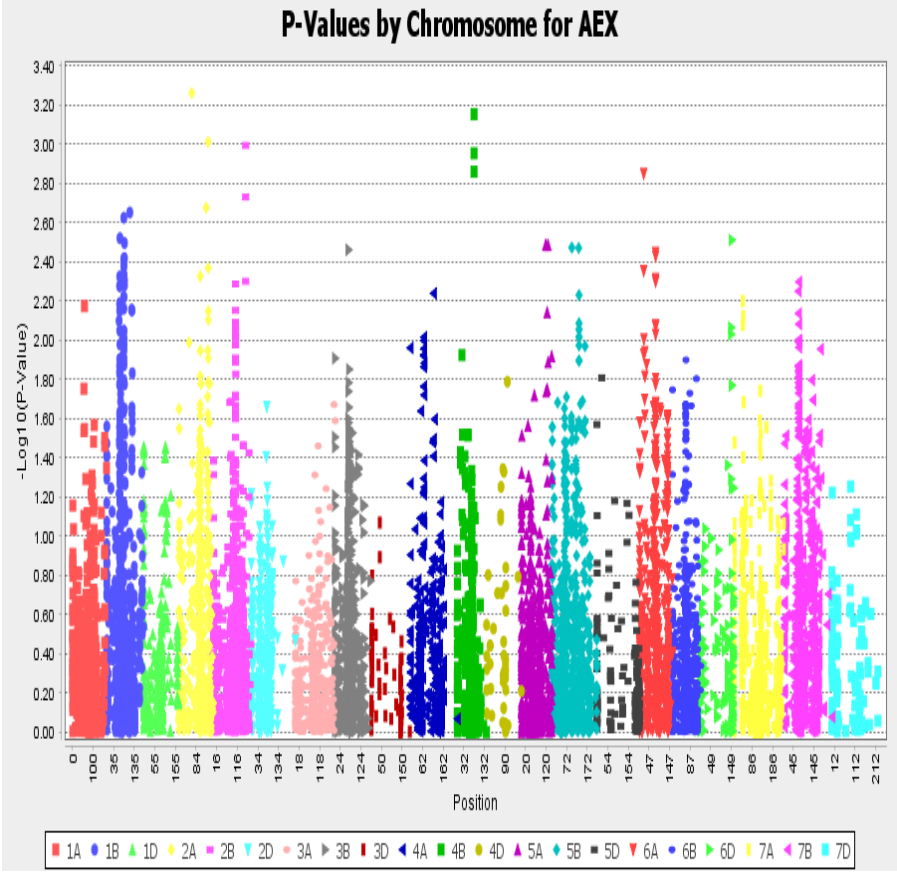
Heterosis over best parent (HB%)

$=[(F1-BP)/BP\times100]$

Where,
MP= mean mid parent
BP= mean better parent value.

QTLs associated to pollen mass and anther extrusion on chromosome 4B





Pre-breeding
SHW: significant contribution for the development of elite lines and varieties

- How can we increase the utilization of the genetic resources conserved ex-situ?
- Would it not be easy to first identify duplications, characterize the unique sets and plan effective introgression strategy?
- Trait based introgression, pyramiding and germplasm sharing
- Collaboration on key location phenotyping
- Development of new synthetics and other translocations
- Balance of investment in phenotyping vs genotyping

Capacity building: short and long term trainings

- Short term training : Classical and Molecular Approaches in Wheat Breeding

- MSc & PhD Students

Name	Sex	Country	Degree	Study area
Sahar Bennani	F	Morocco	PhD	Drought tolerance
Samira El-Hanafi	F	Morocco	PhD	Hybrid wheat
Sawsan Tawkaz	F	Syria	PhD	DH
Kenza	F	Morocco	PhD	quality
Nawal	F	Algeria	PhD	Drought tolerance
Elfadil	M	Sudan	PhD	Heat stress
Tilahun	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
Mathewos	M	Ethiopia	PhD	Stem and leaf rust

Acknowledgements

- ICARDA's Wheat Team+ M.Sc. and PhD students
- NARSs in the CWANA + SSA
- INRA-Morocco; ARC-EGYPT; AUB & AREC-Lebanon; EIAR-Ethiopia; ARC-Sudan and Turkey
- WHEAT CRP, GRDC, AfDB, Arab fund, Kuwait fund; ACIAR- India, ICARWIP, TAAT,

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Thank You!