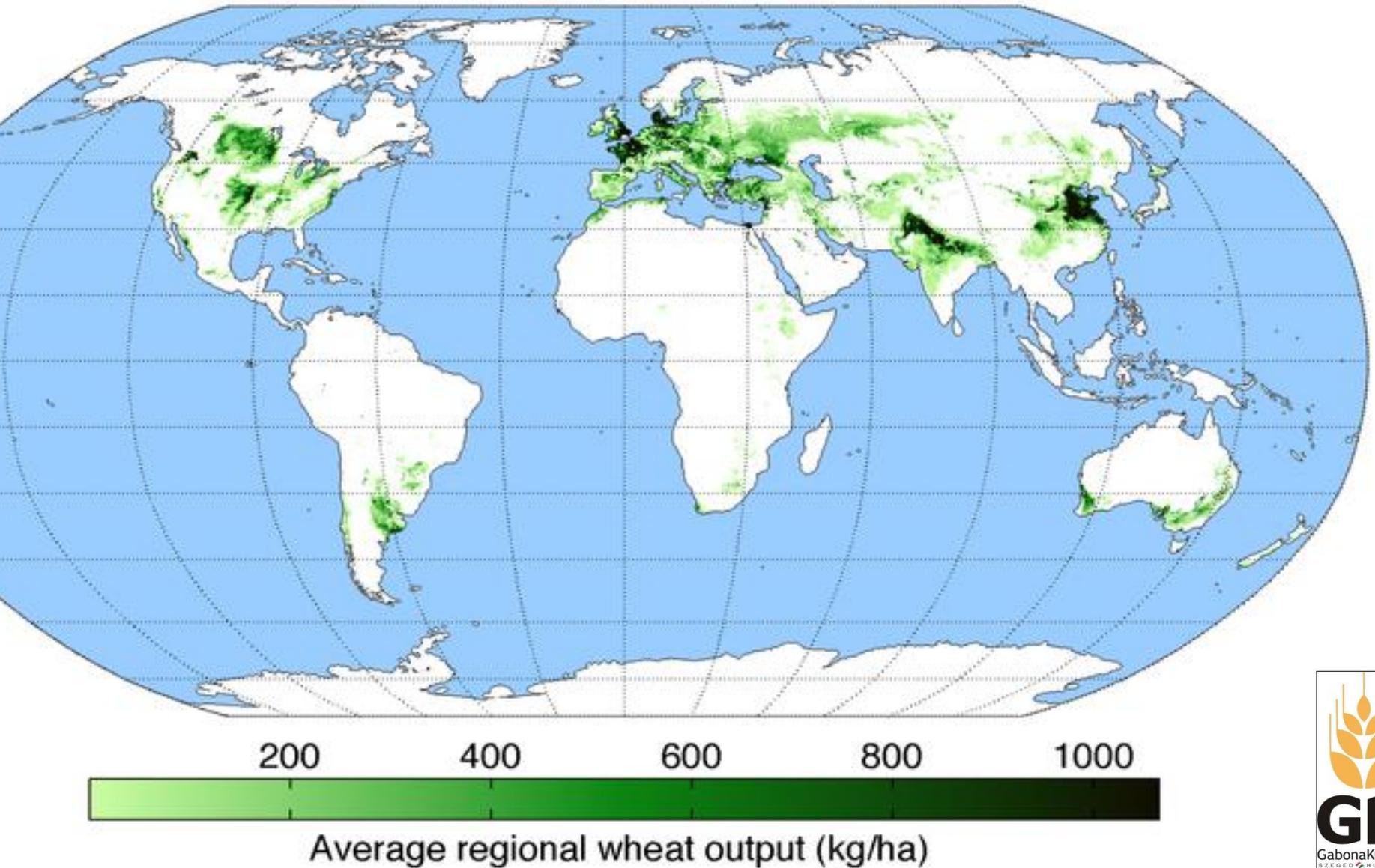


Breeding wheat for tolerance to drought at the Cereal Research Non-Profit Company

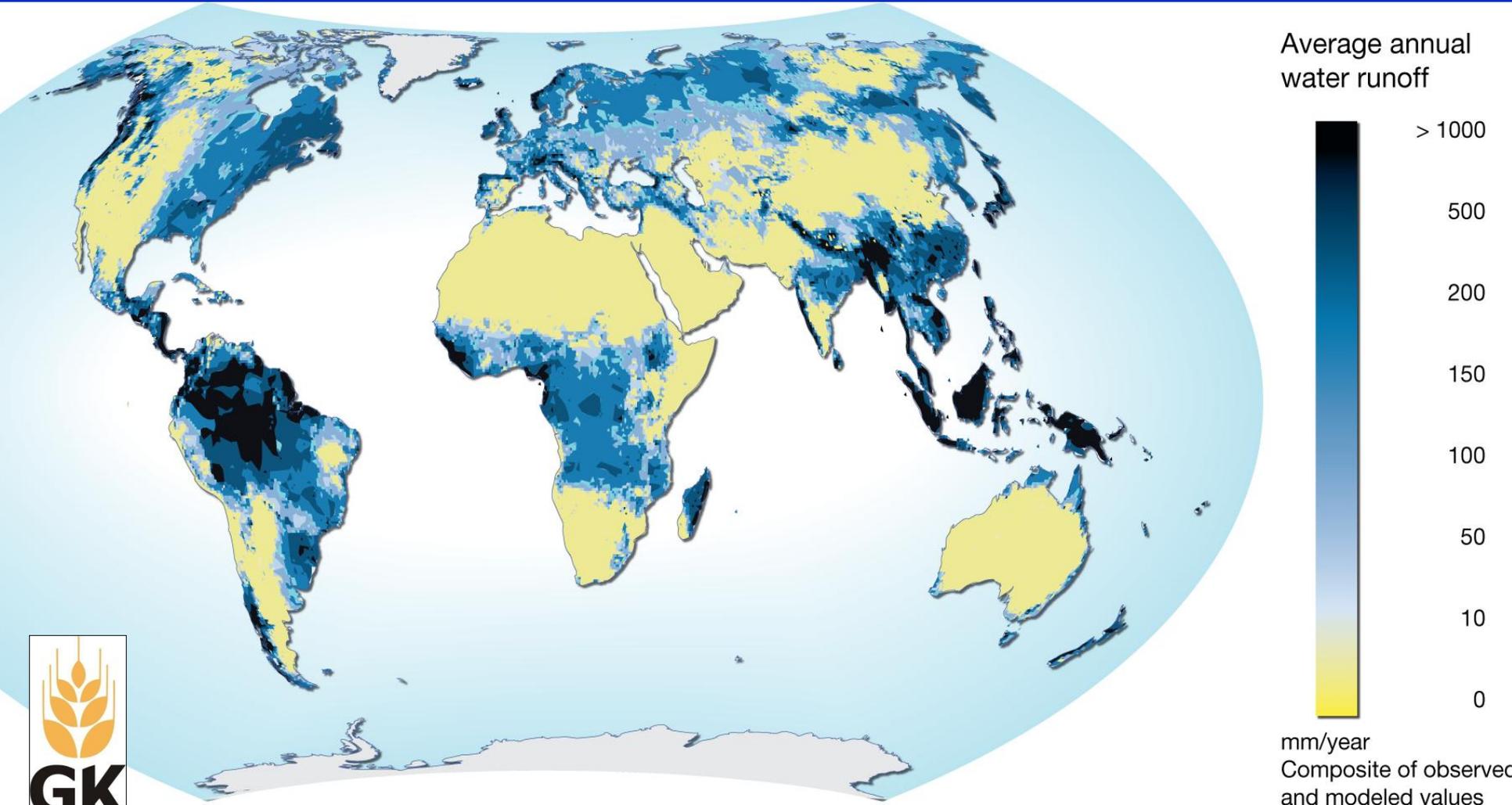
László Cseuz

Cereal Research Non-Profit Co.
H-6701 Szeged, POB 391 Hungary
laszlo.cseuz@gabonakutato.hu

World map of wheat



World map of drought



Average annual
water runoff

> 1000

500

200

150

100

50

10

0

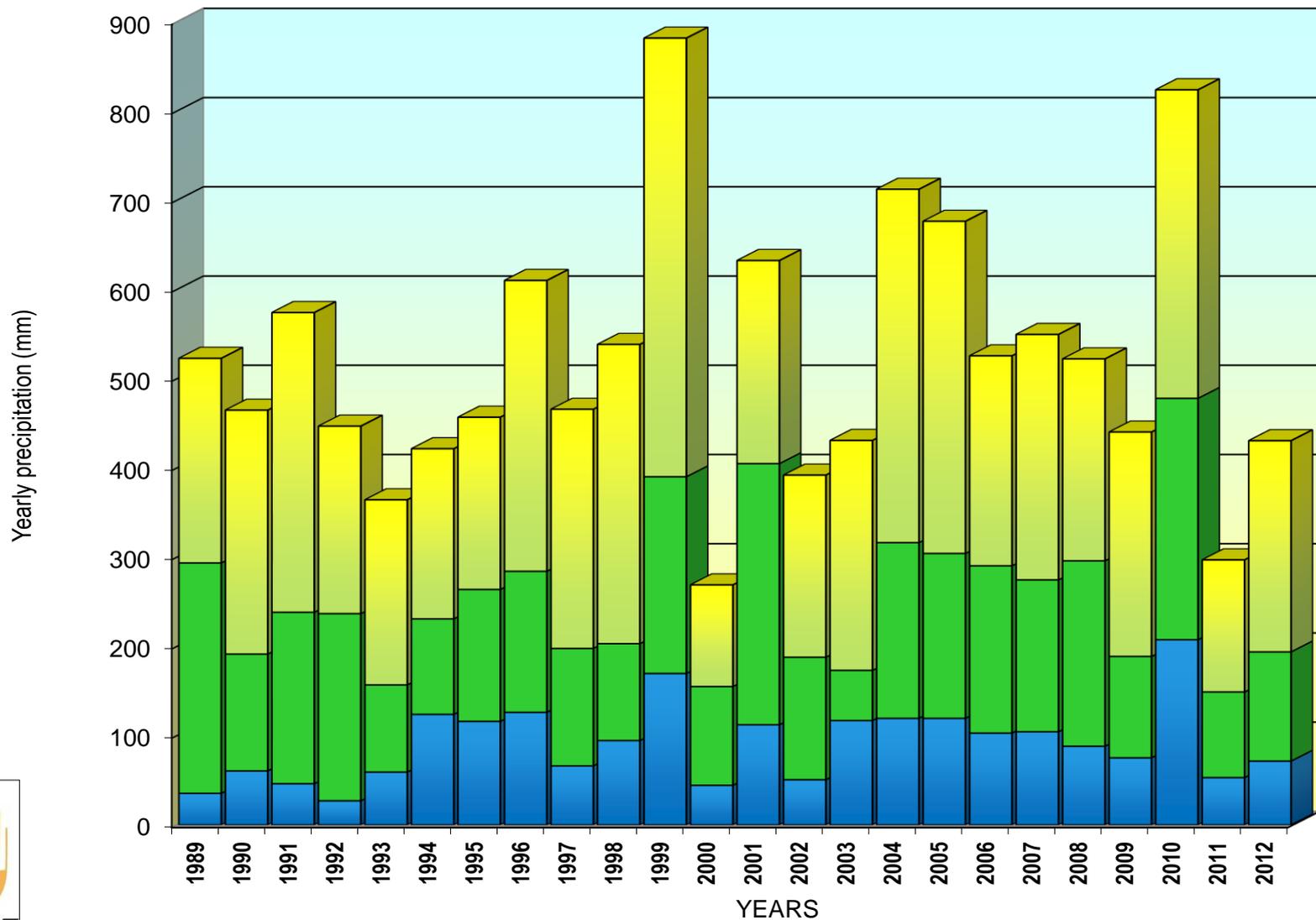
mm/year

Composite of observed
and modeled values

Yearly precipitation and its distribution

Szeged, 1988-2012

- harvest-31.12.
- 01.04.-harvest
- 01.01-01.04



Understanding drought tolerance

- What is drought stress?
- What is „drought tolerance“?
- By what ways plants struggle against drought stress?
- Which are the most successful strategies?
- How we can select for these components of drought tolerance?

What is drought (water) stress?

- „Drought stress develops in the plant when the water demand is higher than the water supply of the ambient environment.”

(Blum, 1988)

- Drought stress is a highly complex phenomenon. Its strength, length, timing, or co-occurrence with other abiotic stresses (heat stress, salt stress, etc.) is altering year after year under our conditions.



What is drought tolerance (DT) ?

- The plant's ability to adapt to water shortages.
- Surviving or economic yielding?
- In high-input agriculture (=practical DT) DT can be characterized by the ratio between grain yield under optimal and stressed conditions. By other words: DT is practically equal to yield stability under drought stress.

Different strategies of plants, or Levitt's (1980) categories:

- Escape mechanism (earliness)
- Dehydration avoidance (water savers (succulent plants) and water users (effective root system))
- Dehydration tolerance (adaptation to drought on cellular level)



How (by which traits) a breeder can select for drought tolerance?

Morphological characters

visual selection

Phenological characters

visual selection

Physiological traits

field & lab tests

Cytology traits

lab tests

Molecular traits

lab tests

How to select?

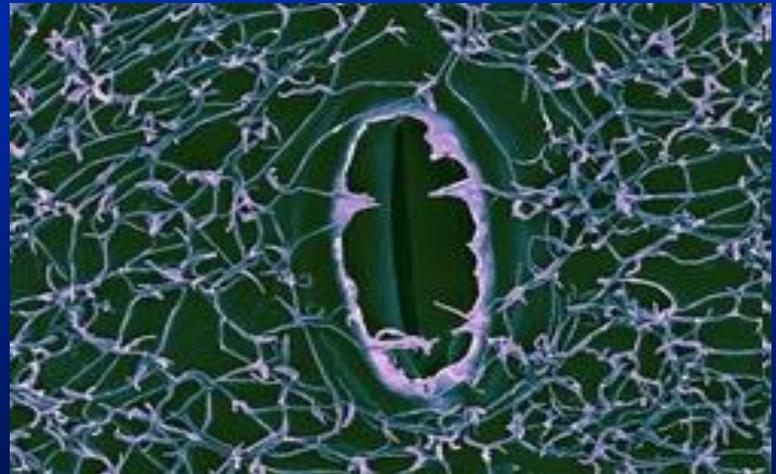
Visual selection (in the nursery)

Morphological traits

- Early root size (lab tests) dehydration avoidance
- Leaves (angle, size, waxyness, hairiness)
- Sturdy leaves (slow senescence)
- Awnead spikes
- Long lasting awns
- Grain (plumpness, stability of grain size)

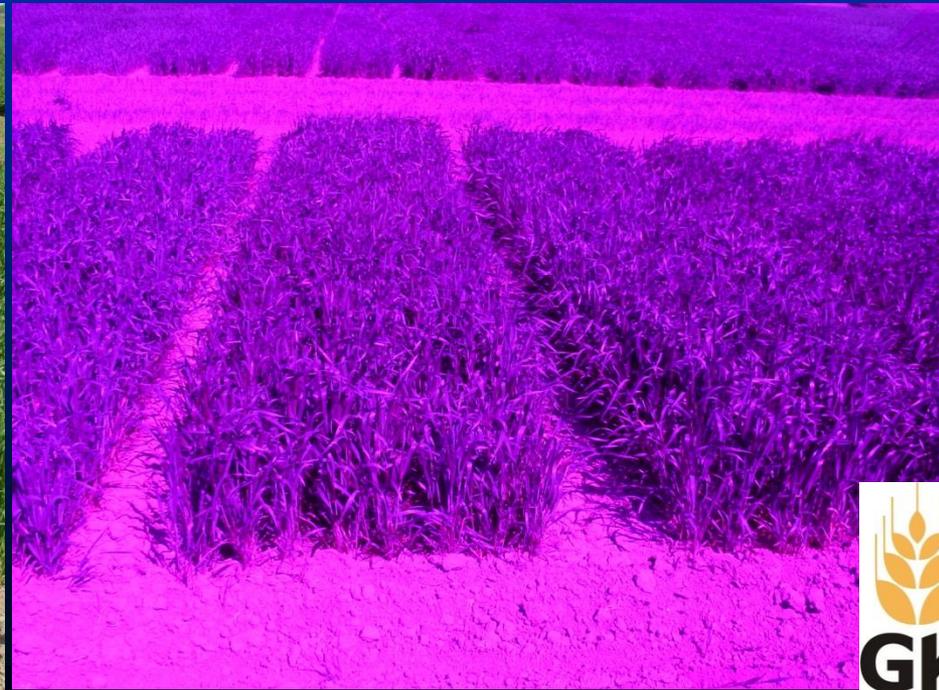
Phenological traits

- Slow development after emergence (rooting type)
- Fast early growth in spring
- Earliness in booting
- Earliness in heading
- Fast ripening (staying green)
- Resistance to biotic stresses



Visual evaluation of stress symptoms

- Leaf coloration (purple, dark green, yellowish)
- Leaf firing (tip necrosis)
- Velocity of lower leaves' senescence
- Leaf rolling (adaptation!)
- Depression of chlorophyll content (turning yellow)
- Grain plumpness
- Stability of plant height
- Stability of grain size



Water retention ability (WRA) of excised flag leaves



Water retention ability (WRA) of excised flag leaves

Materials and methods:

1. Collecting flag leaves and determination of their fresh weight (FW1)
2. 24 hrs incubation and determination of turgid weight (TW)
3. 8 hrs desiccation under controlled conditions and determination of desiccated weight (FW2)
4. After a complete drying determination of dry weight (DW)
5. Determination of relative water content of flag leaves with a fresh weight (RWC1) and desiccated weight (RWC2).
6. Evaluation of reduction in RWC due to the 8 hrs desiccation (WRA).

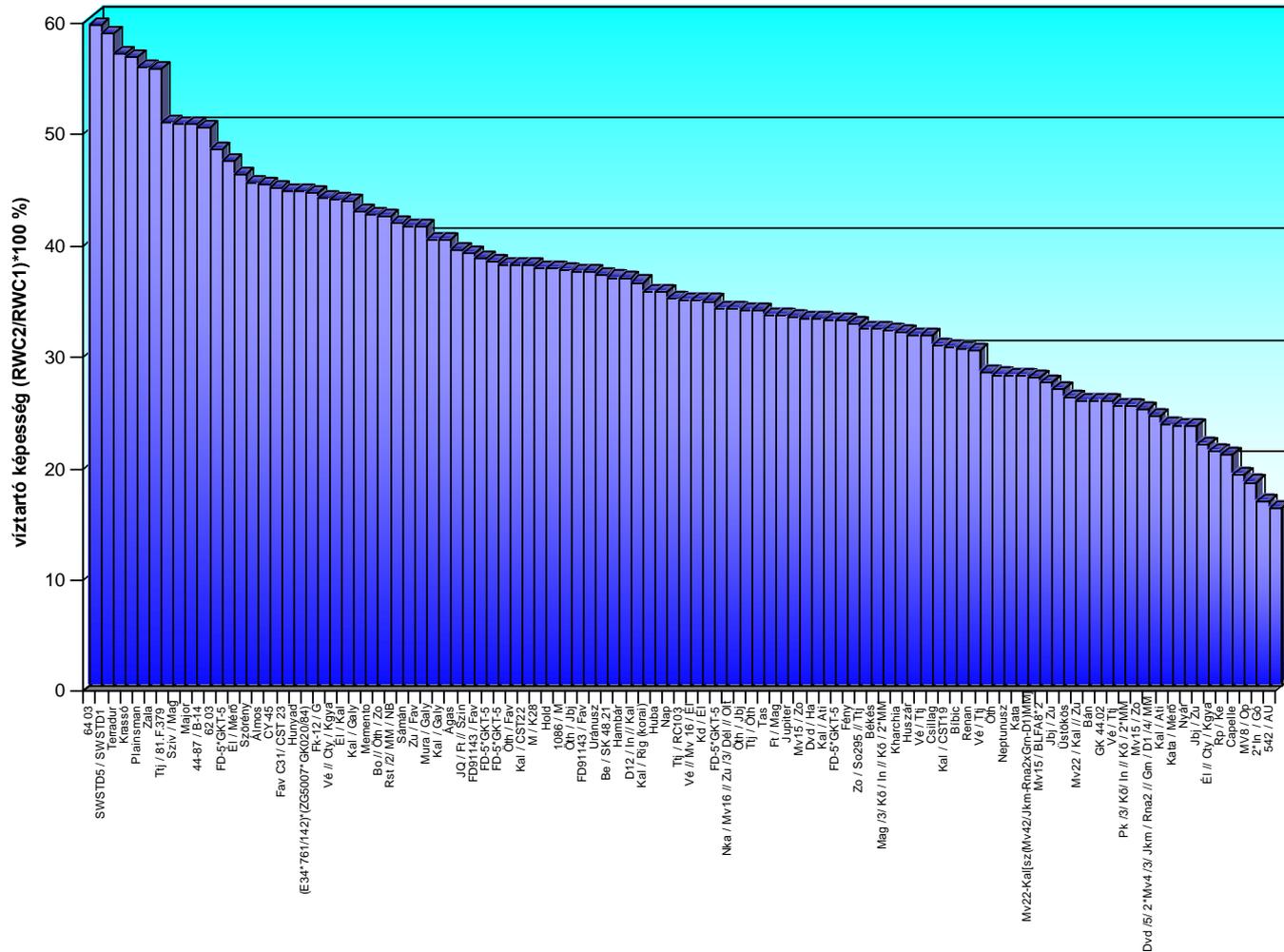
$$\text{RWC1} = (\text{FW1}-\text{DW})/(\text{TW}-\text{DW}) * 100 \%$$

$$\text{RWC2} = (\text{FW2}-\text{DW})/(\text{TW}-\text{DW}) * 100\%$$

Water retention ability:
 $\text{RWC2}/\text{RWC1} * 100\%$



Búza zászlóslevelek víztartó-képessége (kontroll %), Szeged, 2004



a vizsgált genotípusok (100)

Water loss: 40-80 %



desiccated

control

irrigated

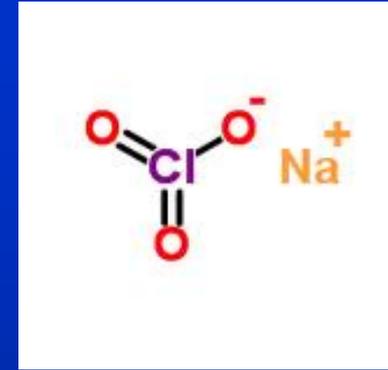
Field trial for drought tolerance

100 genotypes, 3 treatments, 3 repetitions

Evaluation of translocation capacity of stem reserves

Materials and methods:

1. Registration of anthesis



2. Spraying with desiccant (2% solution of NaClO_3) 14 days later



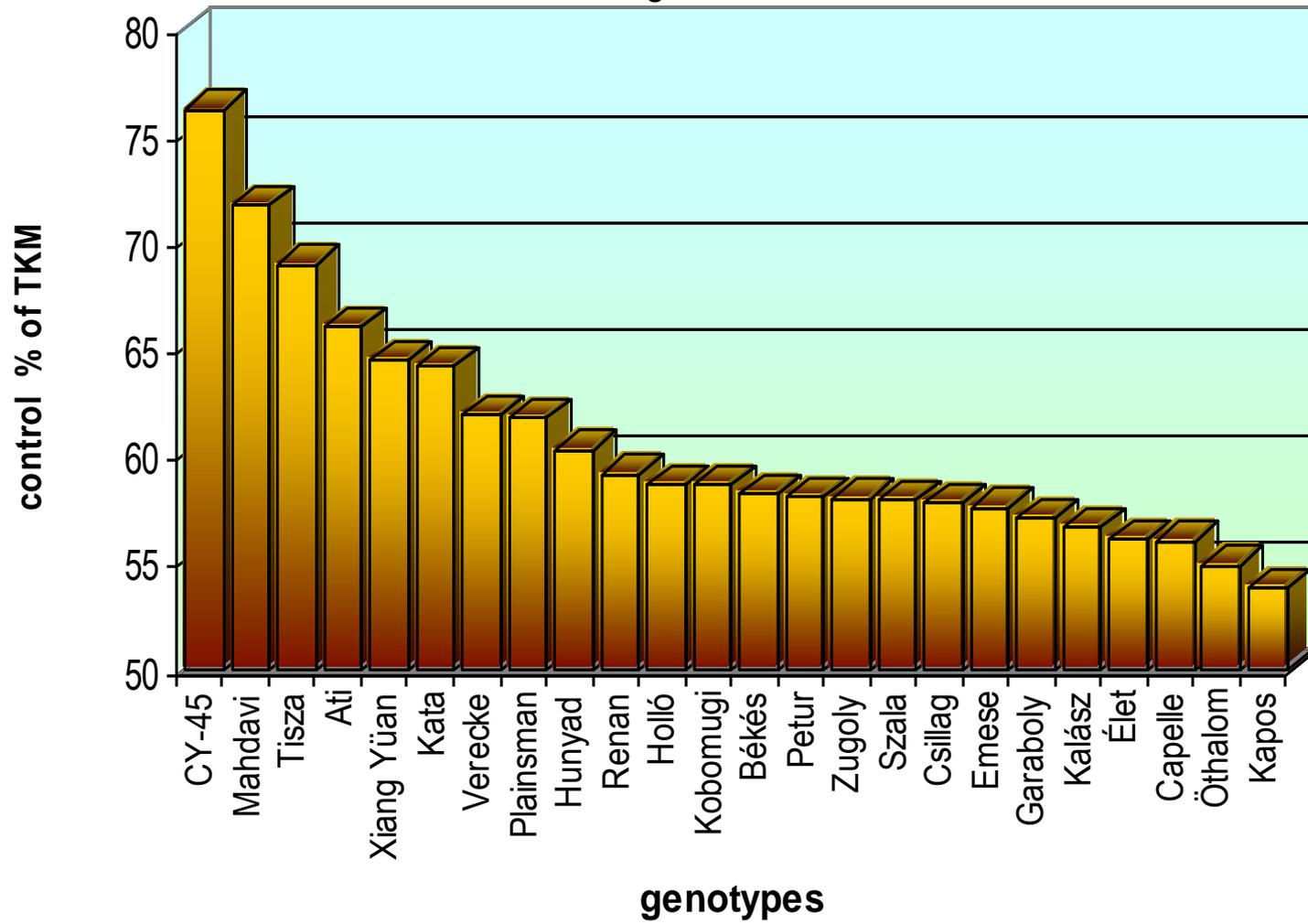
3. Harvesting grain yield at full ripening of control plots

4. Degree of tolerance can be estimated by the reduction in thousand kernel mass

2004 6 19

The effect of desiccation on TKM of wheat genotypes

Szeged, 2007



Depression of TKM: 23-47%

Water withdrawal in the field



Automatic rain shade

60m x 12m area
rain sensors, convertible plastic tunnel
automatic closing-opening mechanism
automatic meteorological measurements
isolated from the side-wetting by drain ditches and
water pump

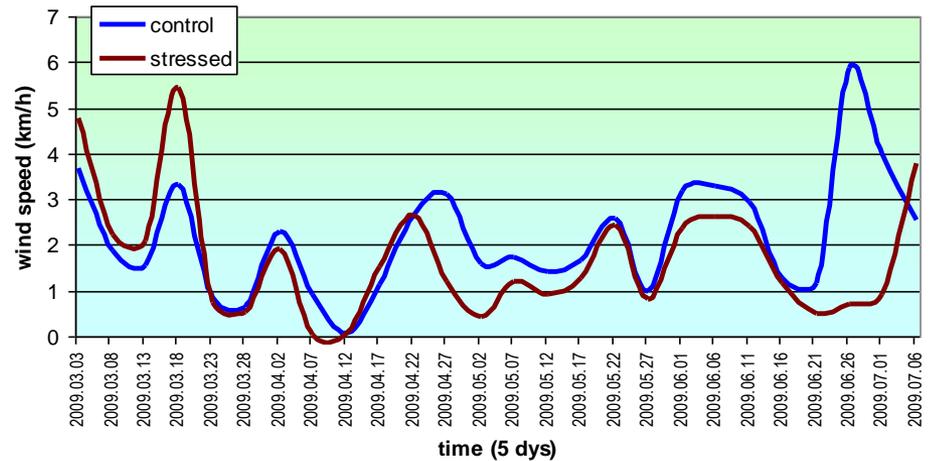


Air temperature, soil temperature, wind speed and sun irradiation between sowing time and harvest

Changing the air temperature in the drought tolerance trial
kíséletben Szeged, 2007/2008



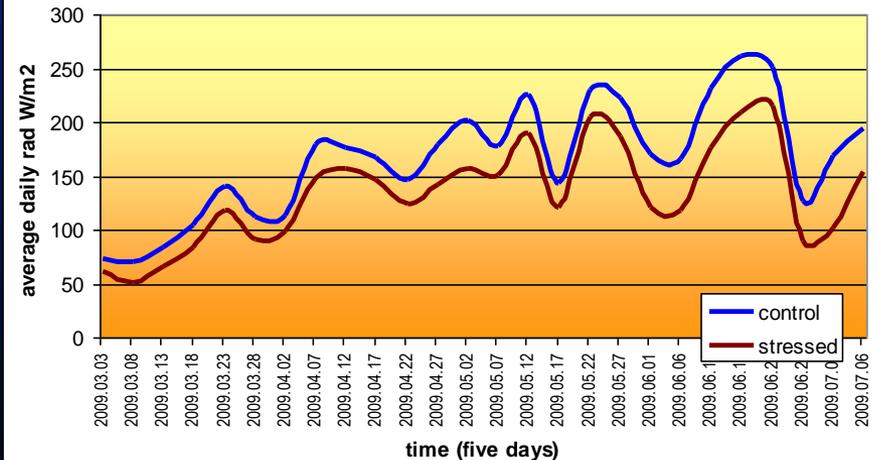
Wind speed in both treatments



Soil temperature between the sowing and harvest in both treatments
Szeged-Kecskés 2007/2008

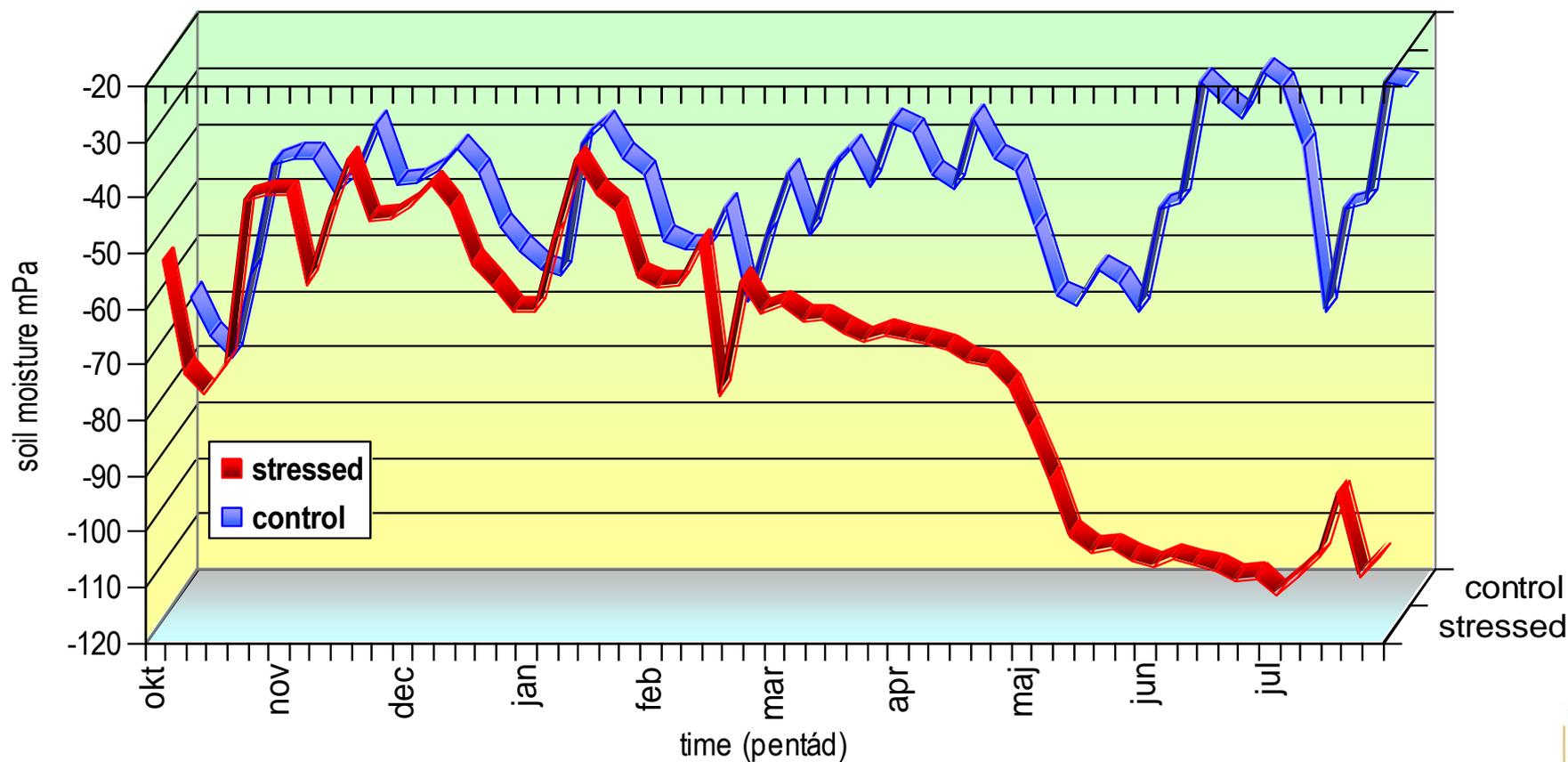


Daily average solar radiation

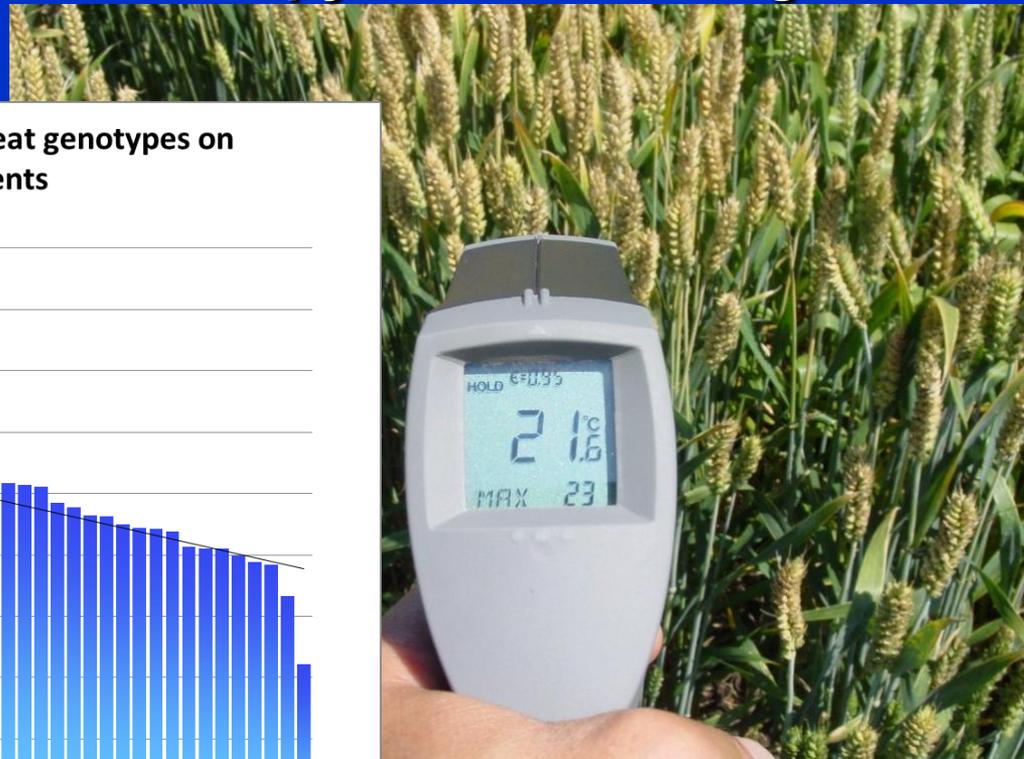


Changes of soil moisture content in both treatments between sowing and harvest

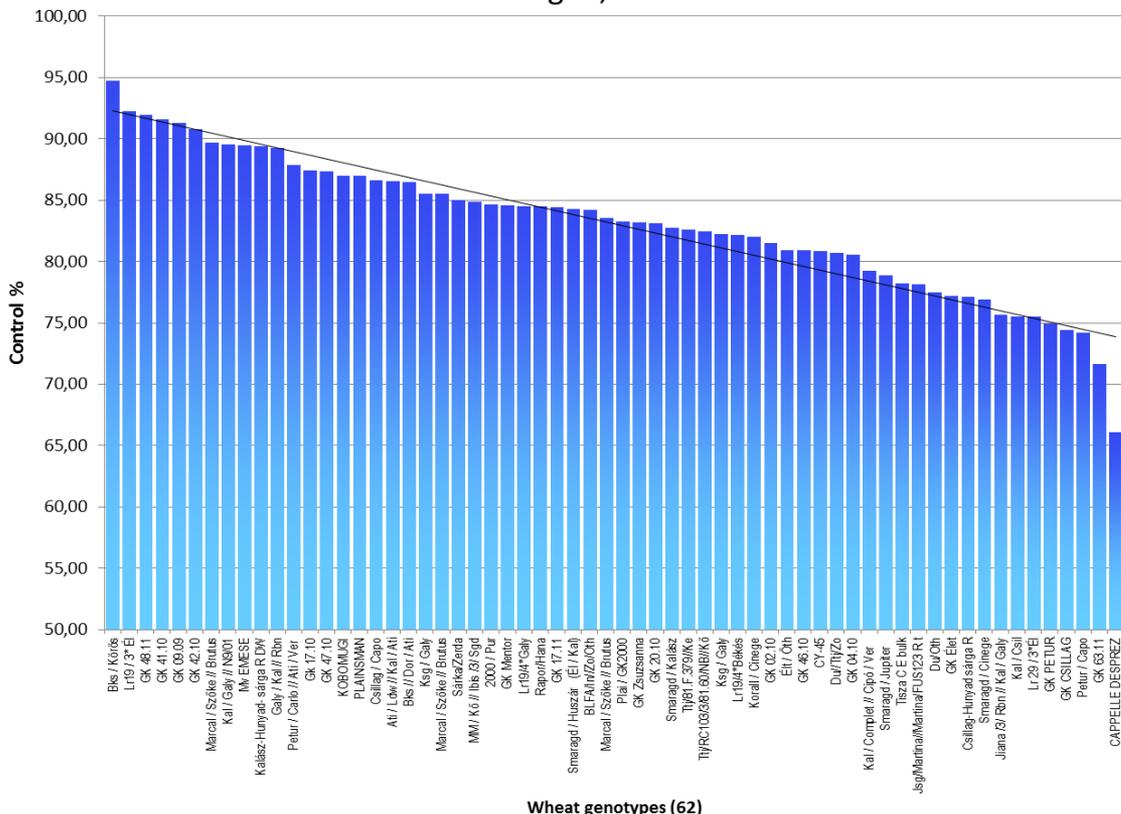
Szeged, 2007/2008



Determining the temperature of canopy surface during severe drought stress



Difference between canopy temperature of wheat genotypes on stressed and non-stressed treatments
Szege, 2012



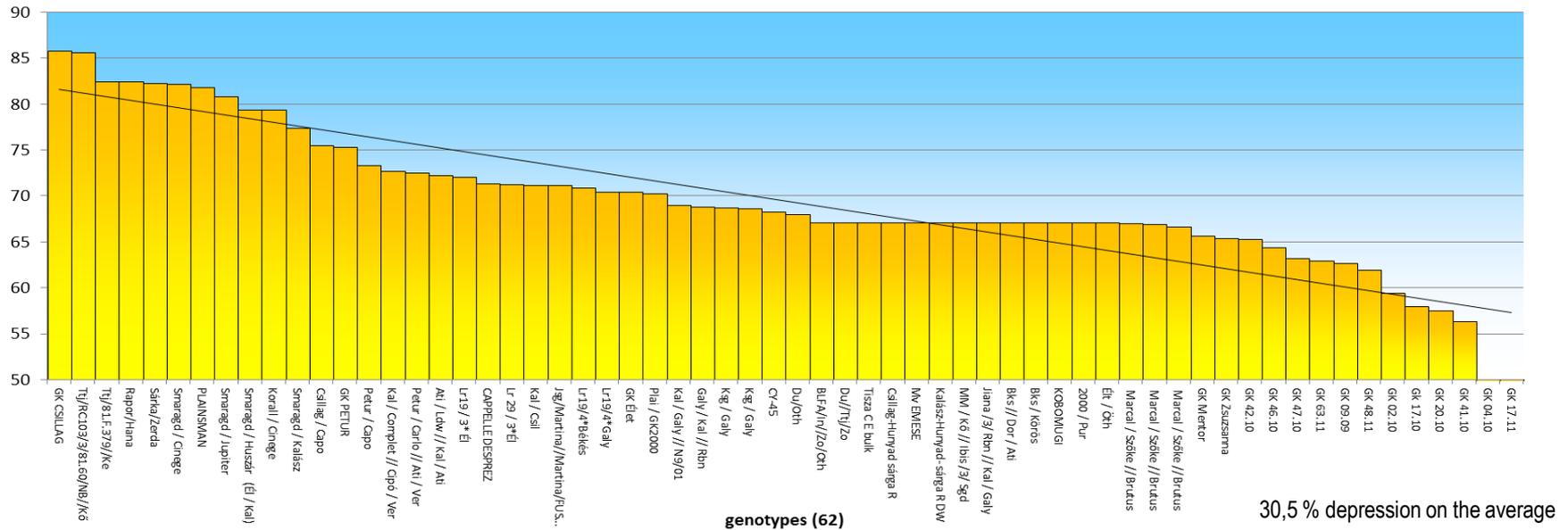
Wheat genotypes (62)

Measurements: 06.12.2012.
 Average temp. of control plots: 25,2 C
 Average temp. of stressed plots : 30,4 C
 Air temperature: 36,0 C

1. Surface temperature is significantly lower in control treatment
2. Difference decreasing with ripening

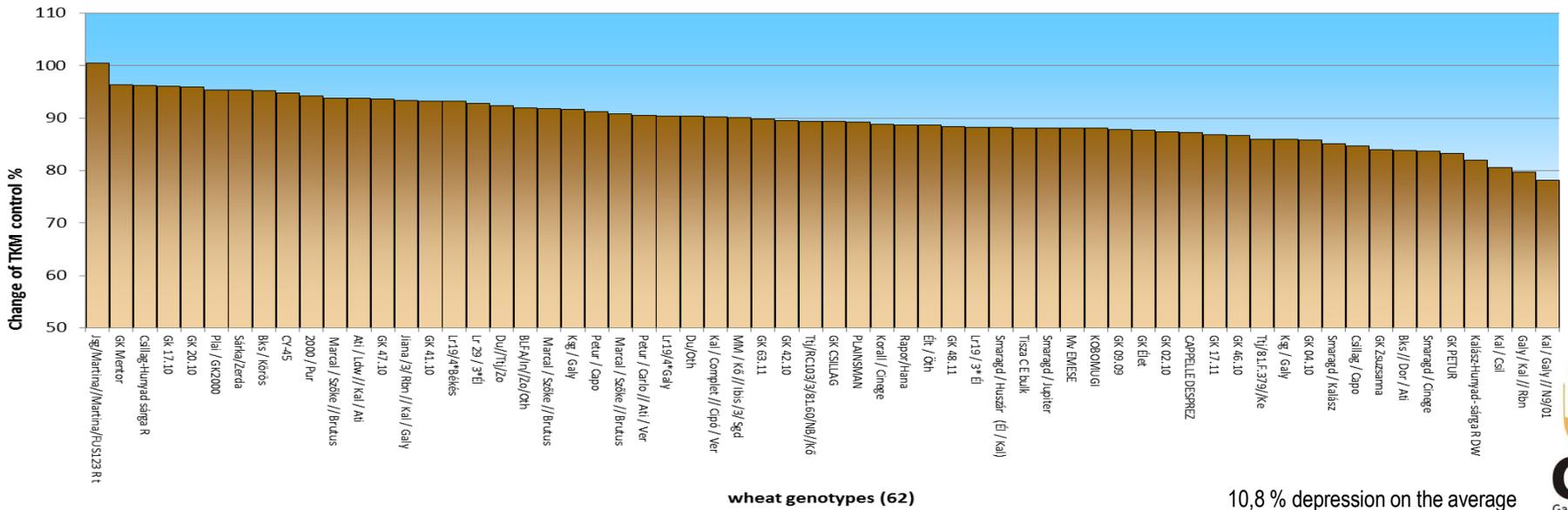
Grain yield depression due to the water withdrawal in the field

Szeged, 2012



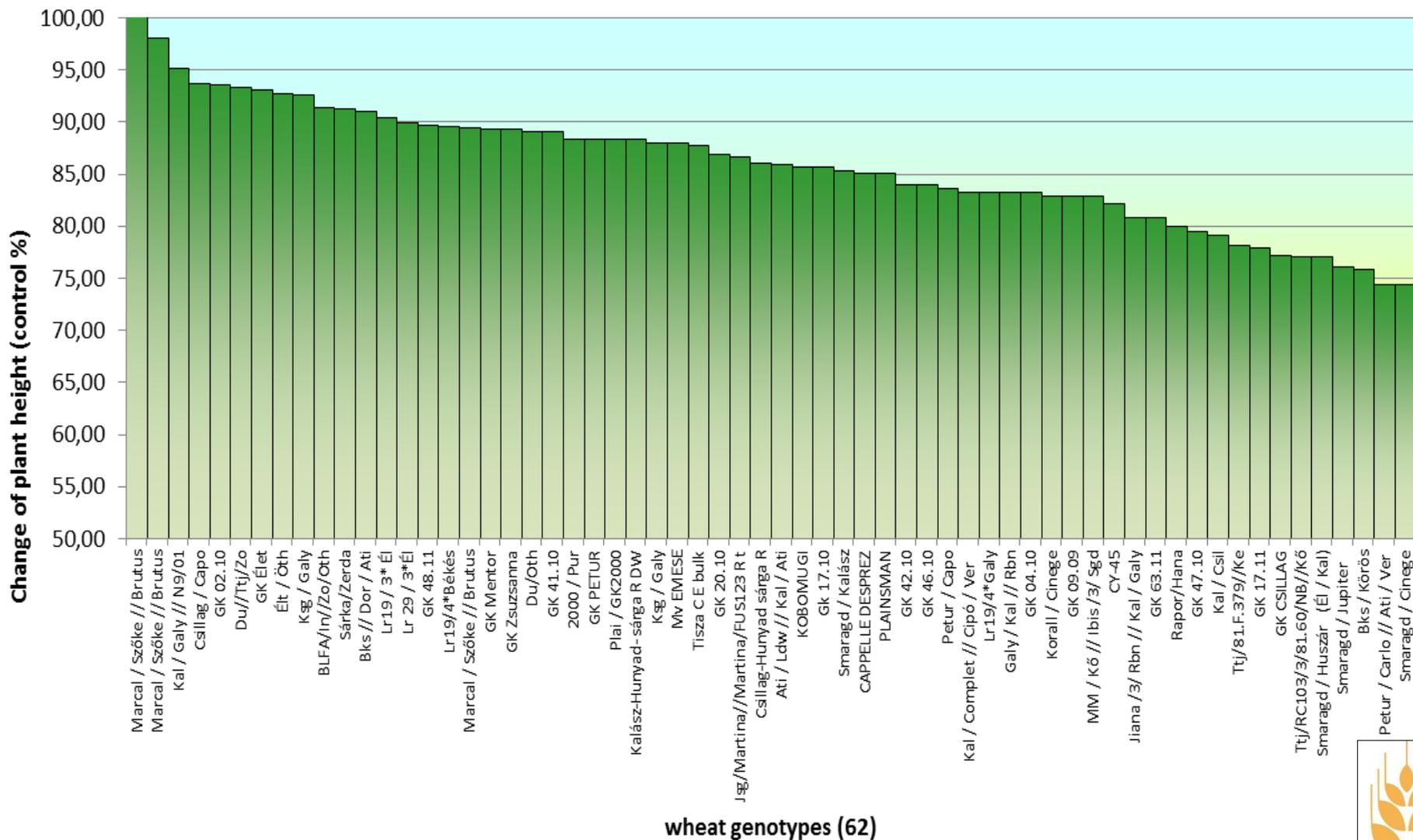
TKM depression due to the water withdrawal in the field

Szeged, 2012



Plant height depression of wheat genotypes due to the water deficit

Szeged, 2012



Depression of plant height: 0 – 24%

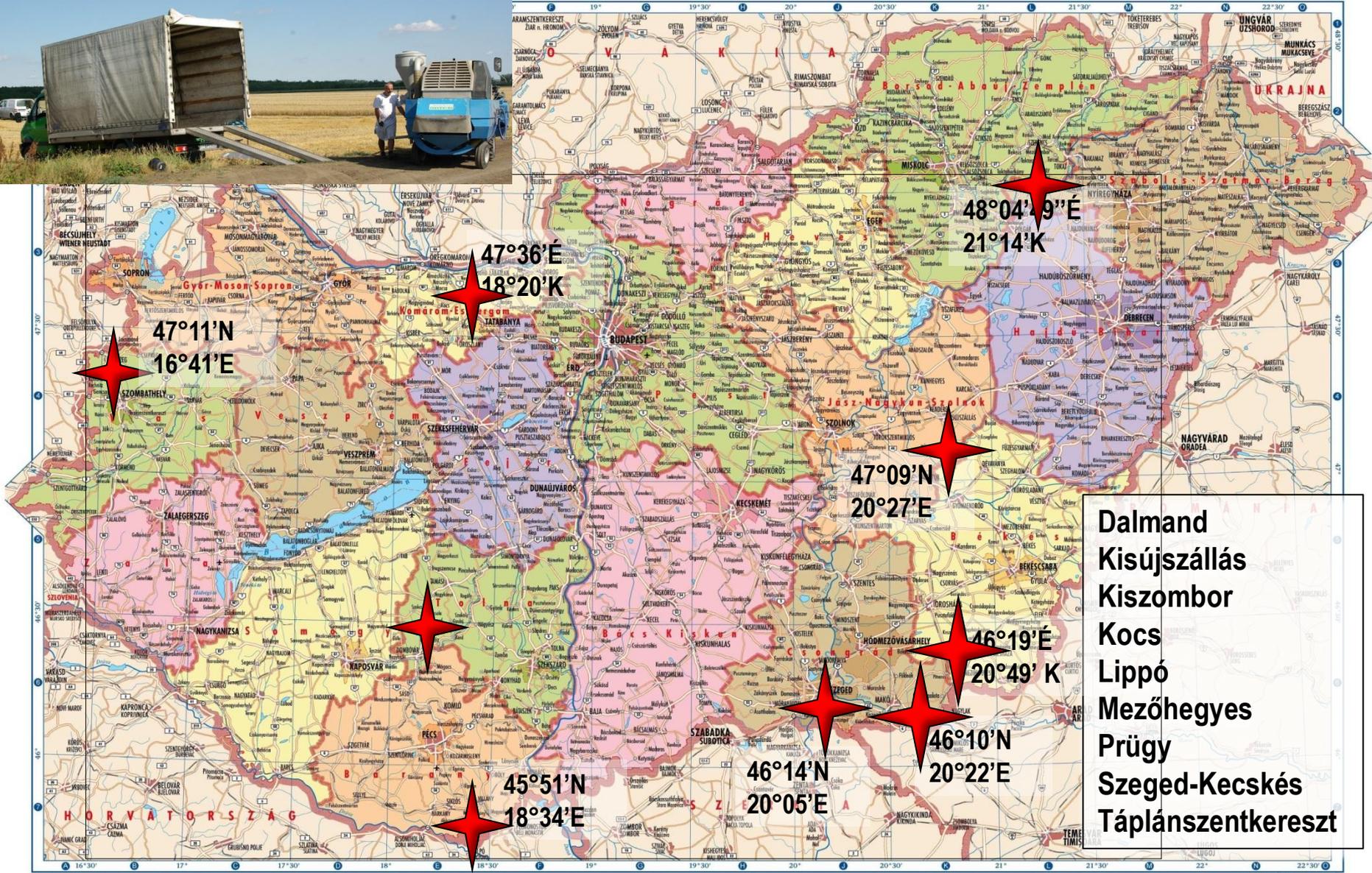


Treatments	Plant height	Heading time	TKM	Grain yield	Canopy temperature
	cm	days	g	g	°C
Control treatment	77,7	136,1	41,5	396,0	25,2
Stress treatment	66,8	133,2	37,0	273,0	30,4
Difference	10,9	2,9	4,5	123,0	-5,2
<i>LSD. %</i>	5,3	1,5	4,2	26,9	27,9
Control %	86,0	97,9	89,1	68,9	120,6

Correlations between some measured traits (TKM, grain yield, plant height, canopy temperature)

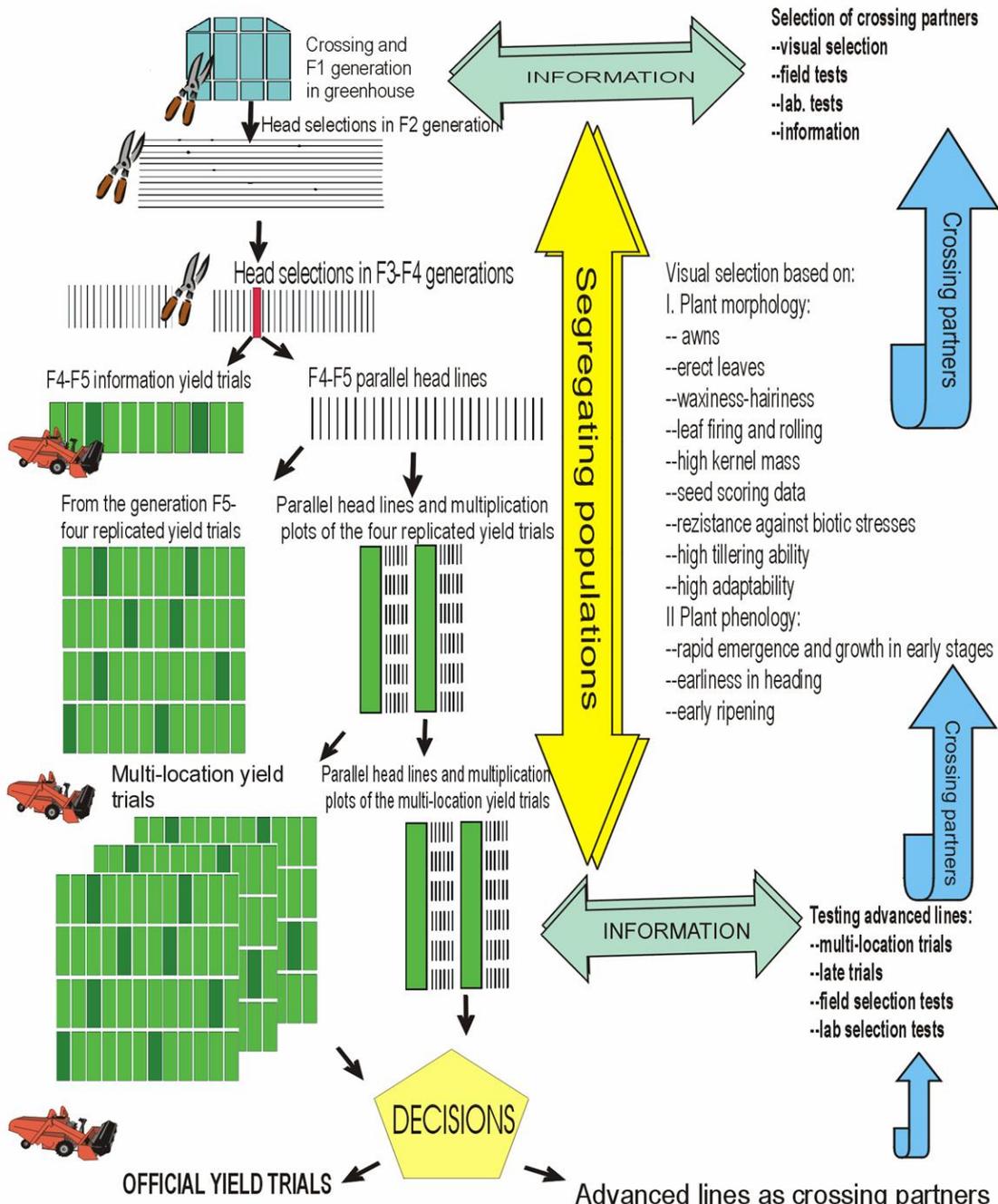
	Plant height	Temp. I.	Temp. II.	TKM	Grain Yield
Plant height	1				
Temp. I.	0,358584***	1			
Temp. II.	0,227767*	0,292961**	1		
TKM	0,228046*	0,008088	0,278769**	1	
Grain Yield	0,5873849***	0,317272**	0,143481	0,260127**	1

Multi-location (9) trials of advanced lines



- Dalmád
- Kisújszállás
- Kiszombor
- Kocs
- Lippó
- Mezőhegyes
- Prügy
- Szeged-Kecskés
- Táplánszentkereszt

Utilizing some selection methods for producing wheat genotypes that tolerant to abiotic stresses



Xing partners
Exotic materials
High yielding lines

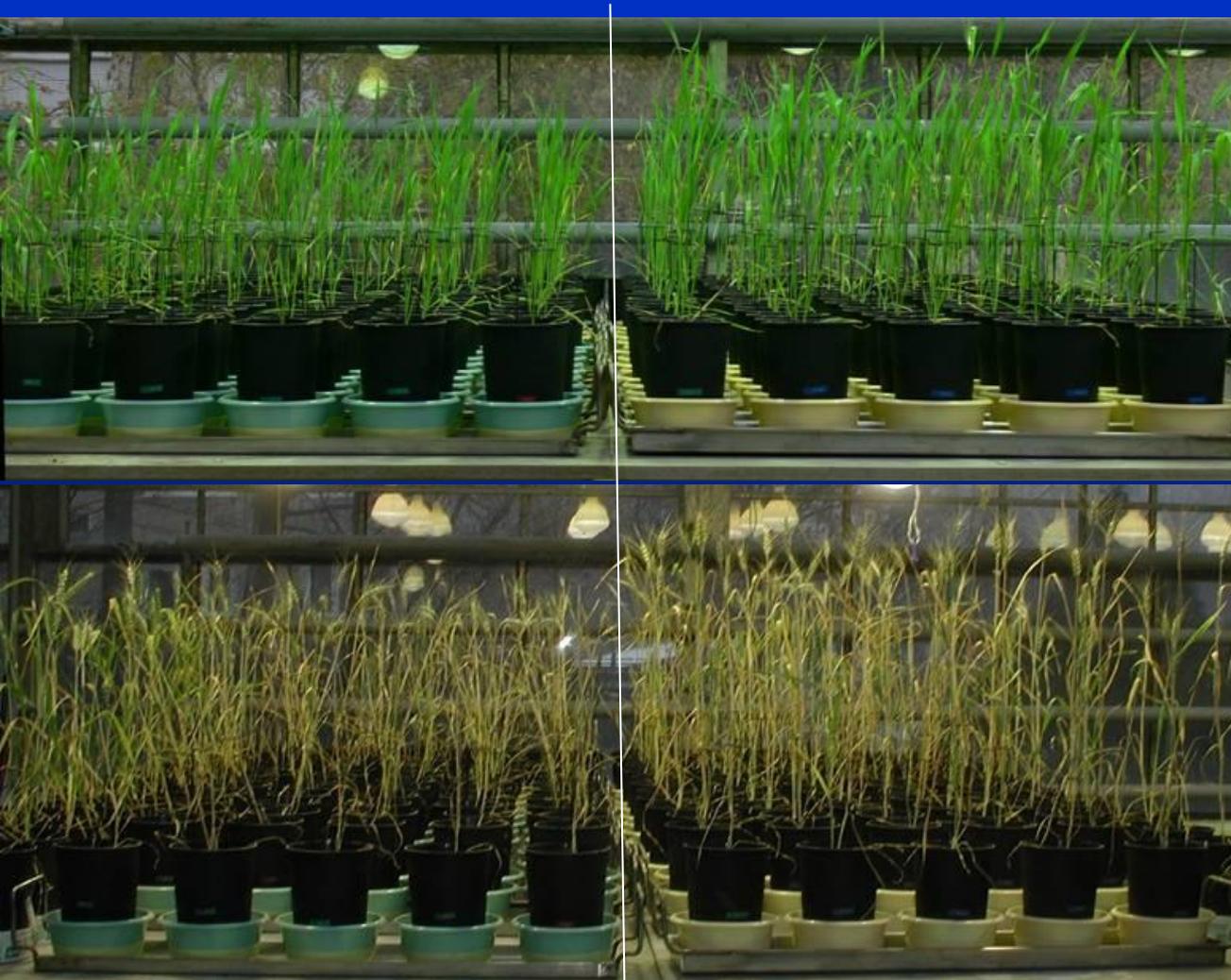
Segregating populations
F2 – F4 head rows
Visual selection

B & C lines
F4-F6 plots
Visual selection
Yield performance tests
from one (or two) location

Advanced lines F6-
Multi-location
performance tests
Visual selection
Simple lab tests
Rain shelter tests

Complex stress-diagnostic system

20% of water capacity „drought” 60% of water c., „control”



3 dimensional imaging system (green pixels)

Automatic photography from 11 directions

Automatic irrigation with specific water dosage and
Plant moving automatic

Infra red gas analyser
CO₂ discrimination,

photosynthesis,

chlorophyll fluorescence

special software for computing the results

Results...

Varieties and variety candidates with higher level of drought tolerance:

1999: **GK Verecke** drought tolerant variety

2001: **GK Csongrád** drought tolerant variety

2005: **GK Békés**, **GK Csillag**, highly adaptable cultivars, **GK Hunyad**, drought-stress tolerant genotype

2010: **GK Berény** drought tolerant varieties

2011: **GK Futár** highly adaptable variety

2012: **GK 26.12** drought tolerant candidate



ACKNOWLEDGEMENTS

We acknowledge that present work was supported by the following projects:

"BIOCEREAL" HUSRB /1002/ 214/ 045 IPA Hungarian – Serbian Cross-border
Co-operation Program.

Project on Preservation of Genetic Cereal Resources (MVH, 263/0601/3/14/2011)
2011-2015

Thank you for your attention!