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Aegilops as a source of dietary fiber and drought stress tolerance

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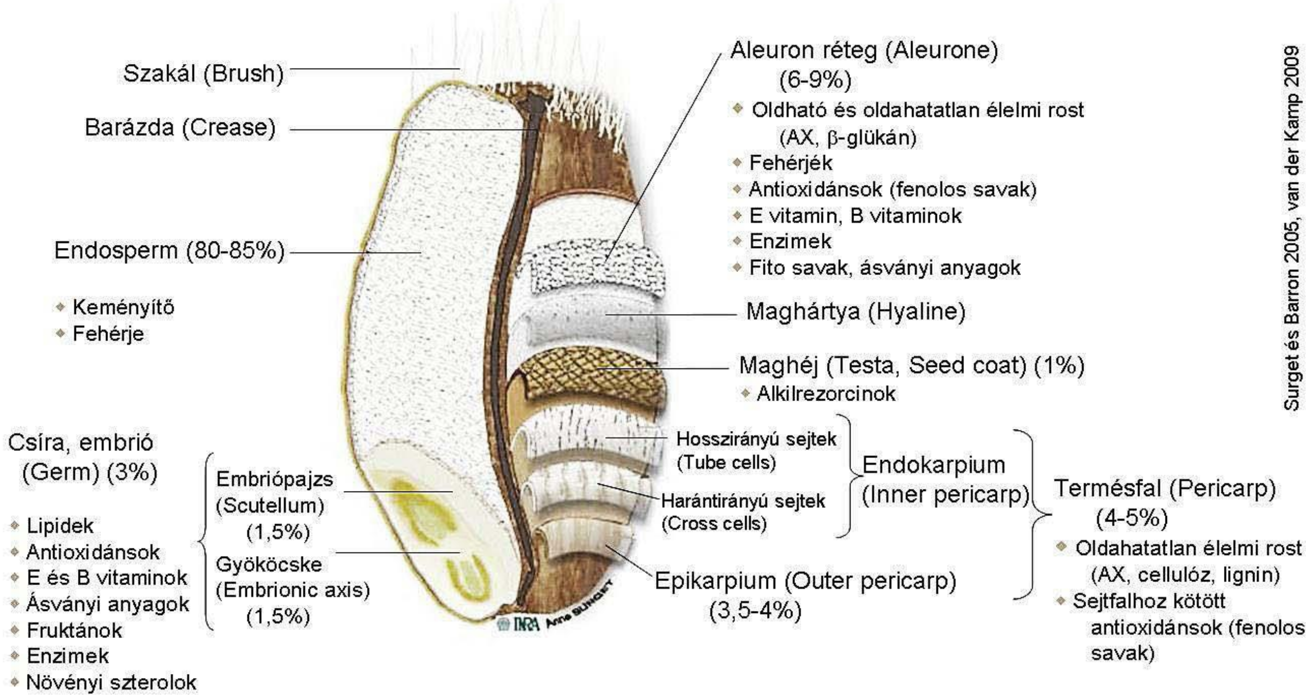
Fiber content of wheat



	SEED	ENDOSPERM	OUTER LAYERS	GERM
Parts of seed	100%	80-85%	13-17%	2-3%
Starch	65-70%	80-85%		
Protein	18-25%	10-15%	16%	25%
Arabinoxylan	4-7%	1,5-5,5%	70%	12%
B-glucan	0,5-5%	0,5-2,5%	6%	5%

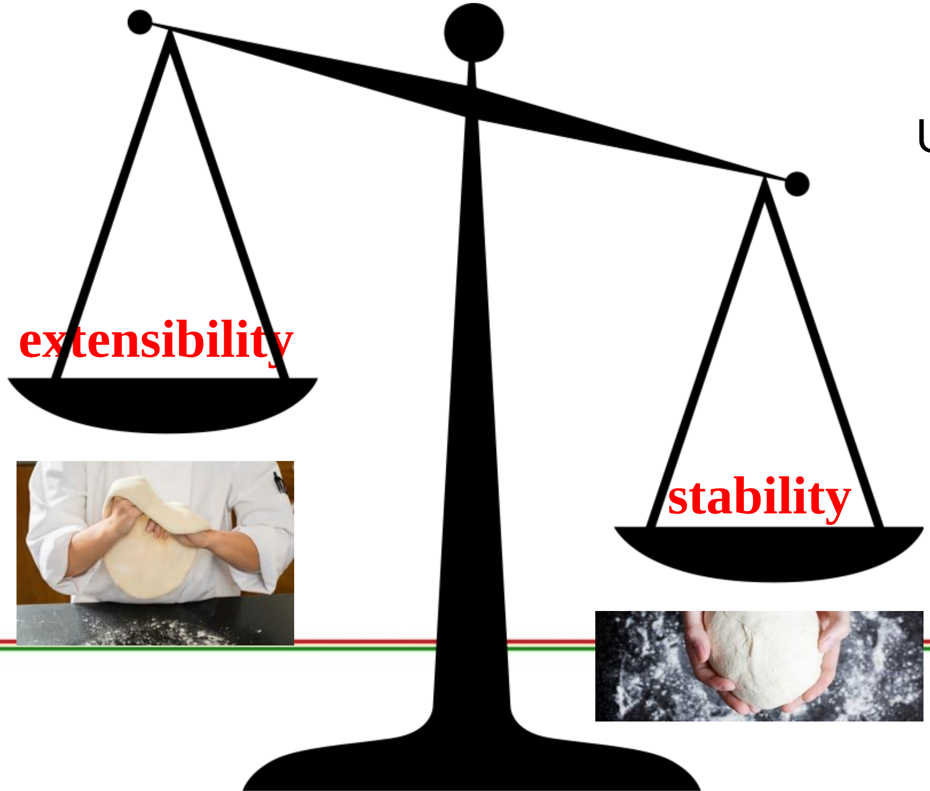
Storage proteins

Wheat gluten proteins

Monomer gliadins (Gli)

Polimer glutenins (Glu)

Unextractable polymeric proteins (UPP%)



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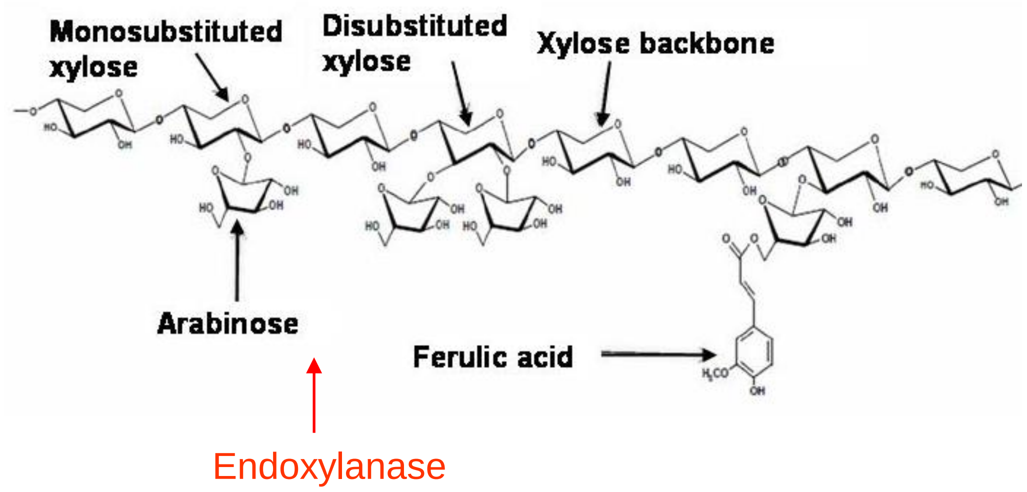
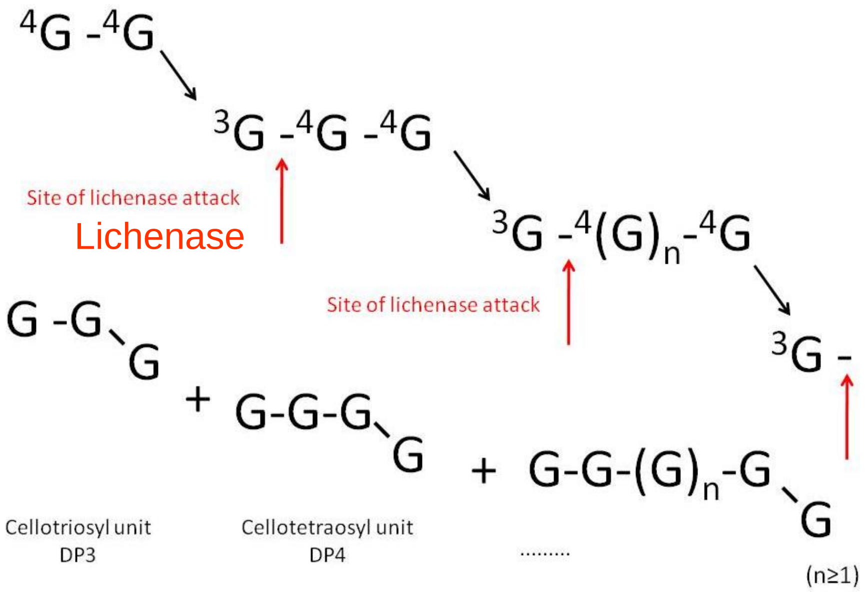
Structure and structural units of dietary fiber molecules

Arabinoxylan (AX)



β - glucan



X, XX, XXX – unsubstituted AXOS

XA3XX, XA3A3XX, XA3XA3XX – monosubstituted AXOS

XA2+3XX, XA3A2+3XX, XA3XA2+3XX – disubstituted AXOS

Characteristics of dietary fibers

Health benefits:

Soluble (WE)-AX

- lowers cholesterol and glucose absorption in the small intestine
- lowers colonic pH and increases changes in intestinal micro-organisms
- reduces the risk of coronary heart disease and type II diabetes

Insoluble (WU)-AX

- lowers transit time of fecal bulk and increase defecation frequency
- binds of carcinogens

Effect on processing:

Wheat AX:

- affect breadmaking quality, increase water absorption
- gluten-starch separation,
- quality of animal feed,
- fermentation to produce alcohol and biofuel

U and M genome of *Aegilops sp*. as potential gene sources of the cultivated wheat

Beneficial traits:

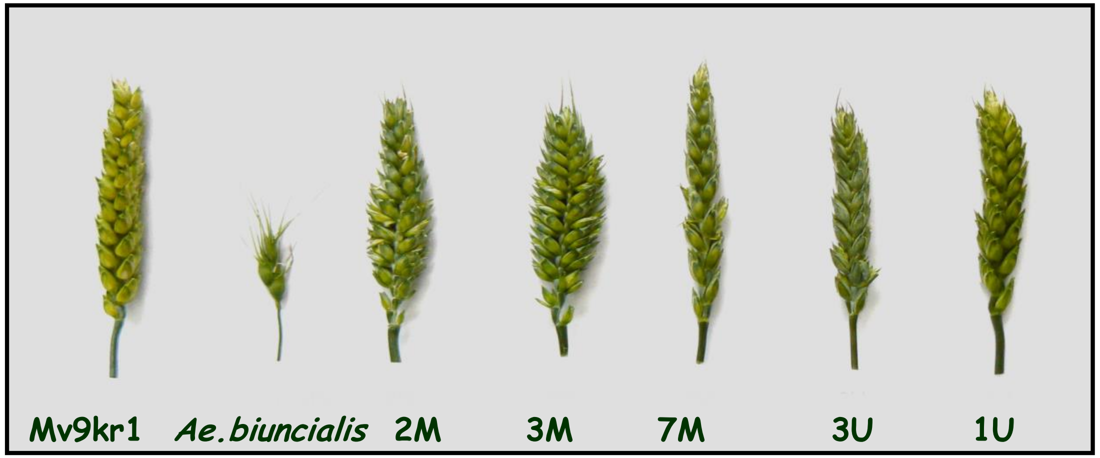
1. **Disease resistance** (to leaf rust, stem rust, yellow rust and powdery mildew) (*Ae. geniculata*- Lr 57, Yr40)

2. **Resistance to abiotic stresses** (tolerance to drought-, heat-, salt- and Al- stress) (*Ae. biuncialis* and *Ae. geniculata* – salt-, drought-, heat-tolerance)

3. **High nutritional value** (high arabinoxylane, β-glucan and microelement content (Fe, Zn)) (*Ae. biuncialis* – AX, β-glucan, Fe, Zn)

Mv9kr1 x Ae. biuncialis MvGB642

F_1 Hybrids → **Amphiploids** → **Disomic additions**



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Schneider et al. (2005) Genome 48, 1070-1082
Molnár et al. (2004) Functional Plant Biology 31, 1149-1159
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Schneider et al. (2008) Euphytica 163, 1-19.

Aims

1. Determine the effects of added *Ae. biuncialis* and *Ae. geniculata* chromosomes on the content and composition of the grain storage protein and DF components of hexaploid wheat under well-watered conditions
2. Determine the effects of chromosomes under drought
3. Determine the effects of drought stress
4. Identify the chromosomal positions of putative orthologs of the key genes determining these components by using *Ae. umbellulata* chromosome sequences

New gene resources for chromosome addition to wheat

Origin of *Ae.biuncialis* and *Ae. geniculata*

Ae. umbellulata
UU
(2n = 2x = 14)

X

Ae. comosa
MM
(2n = 2x = 14)

Ae. biuncialis
$U^bU^bM^bM^b$
(2n = 4x = 28)

Ae. geniculata
$U^gU^gM^gM^g$
(2n = 4x = 28)

- Chinese Spring / *Ae. geniculata addition set – B. Friebe (Kansas State University)*
- Mv9kr1 / *Ae. biuncialis - M. Lángné-Molnár (MTA-ATK)*

Drought stress experiment in the glasshouse

	control	drought
Design	random block	
Soil composition (garden soil:compost: sand)	3:2:1	3:2:1
Soil water content	30 – 35 %	10 – 15 %
Device	Soil Moisture meter, Delta T device, SM100 sensor	
Length of stress		3 weeks from Zadoks-41 developmental stage
Seed quantity studied	Seed of 10 plants	

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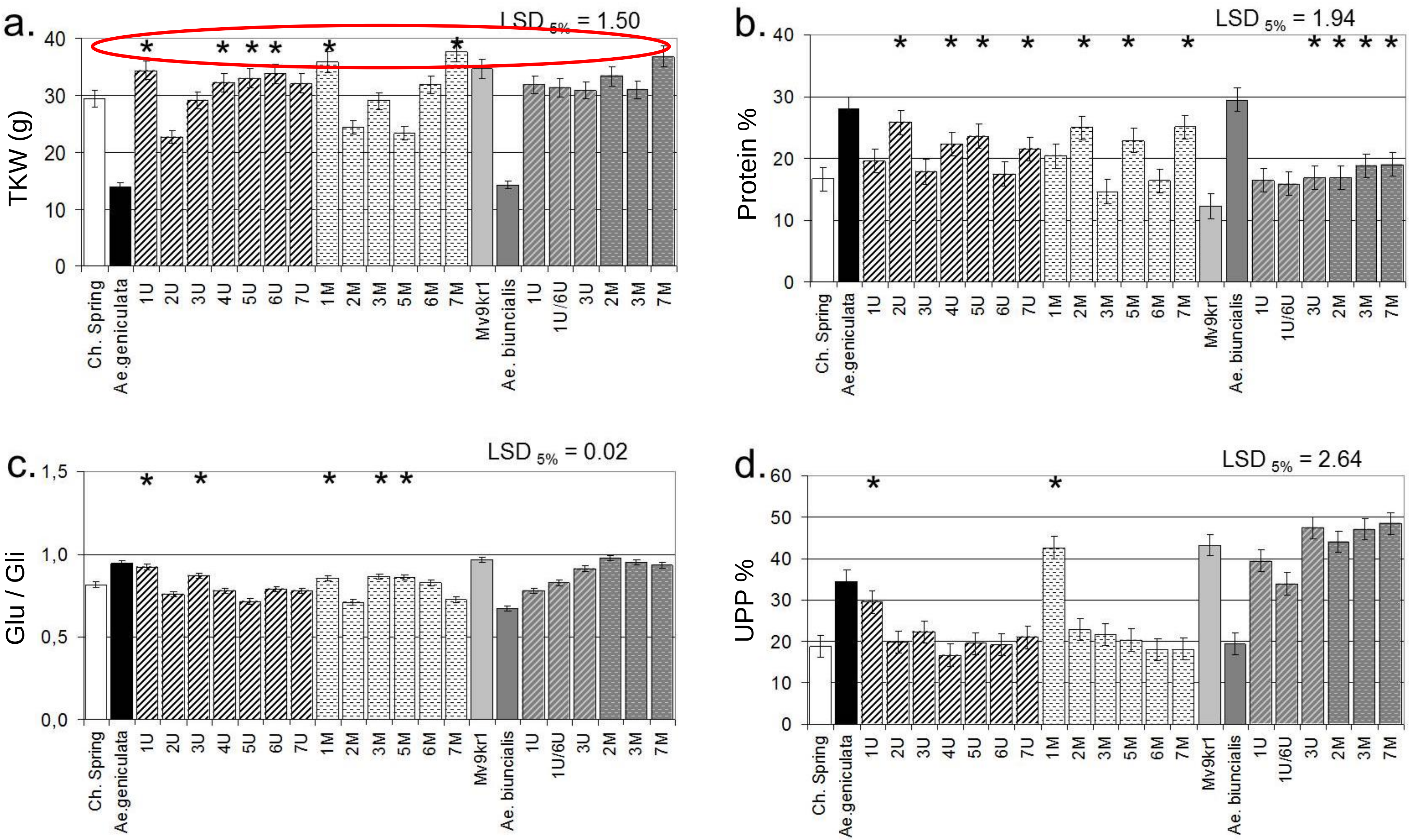
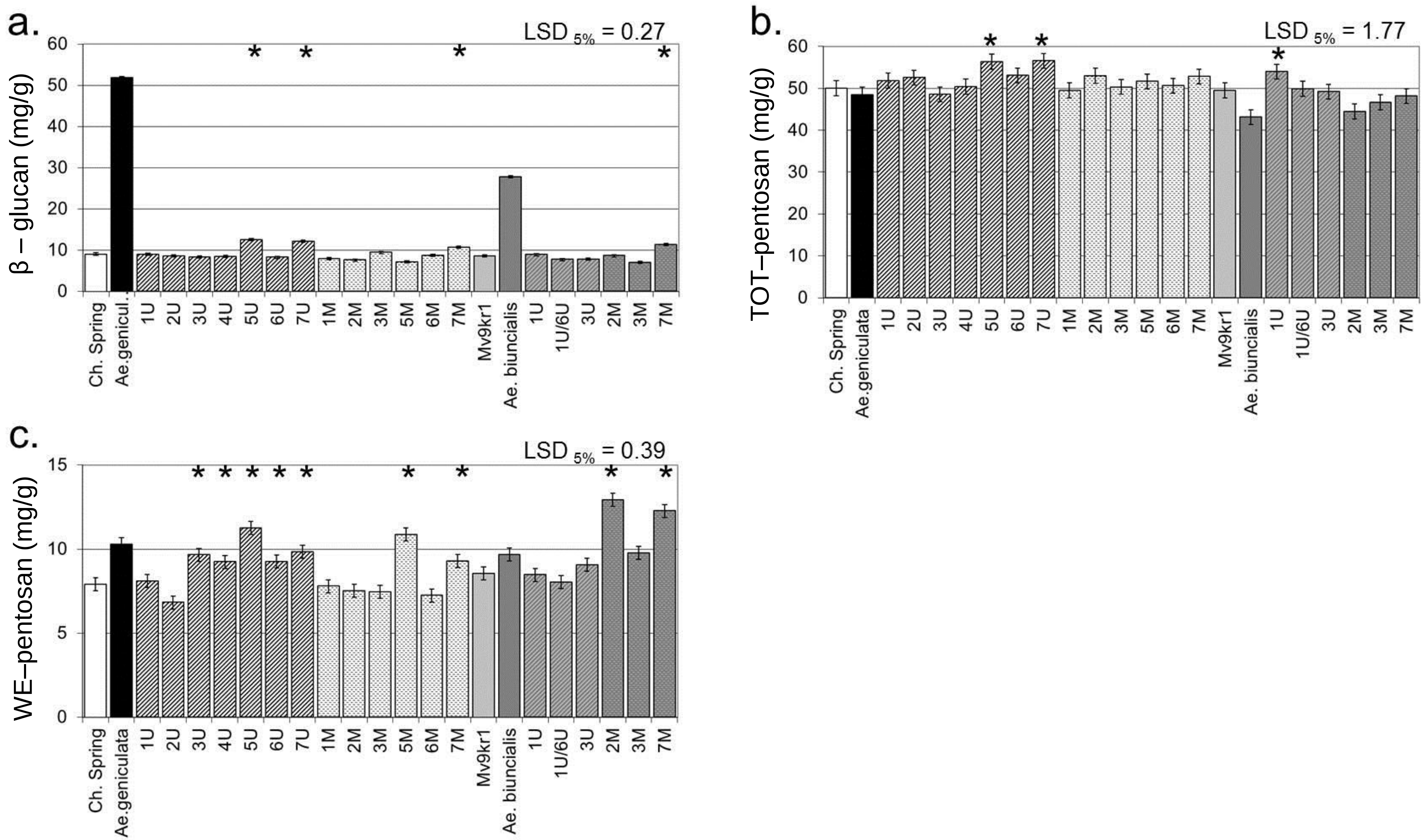
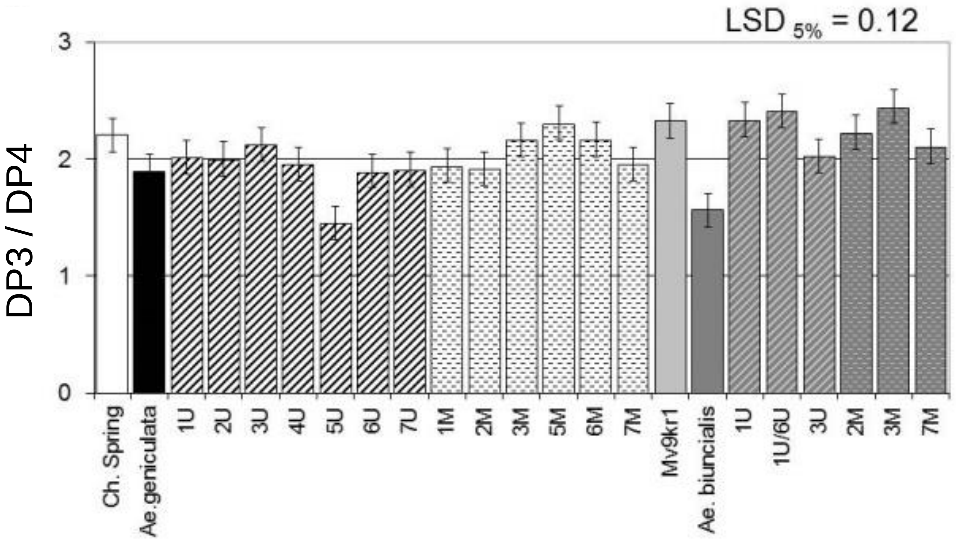
Effect of chromosome additions on wheat storage proteins

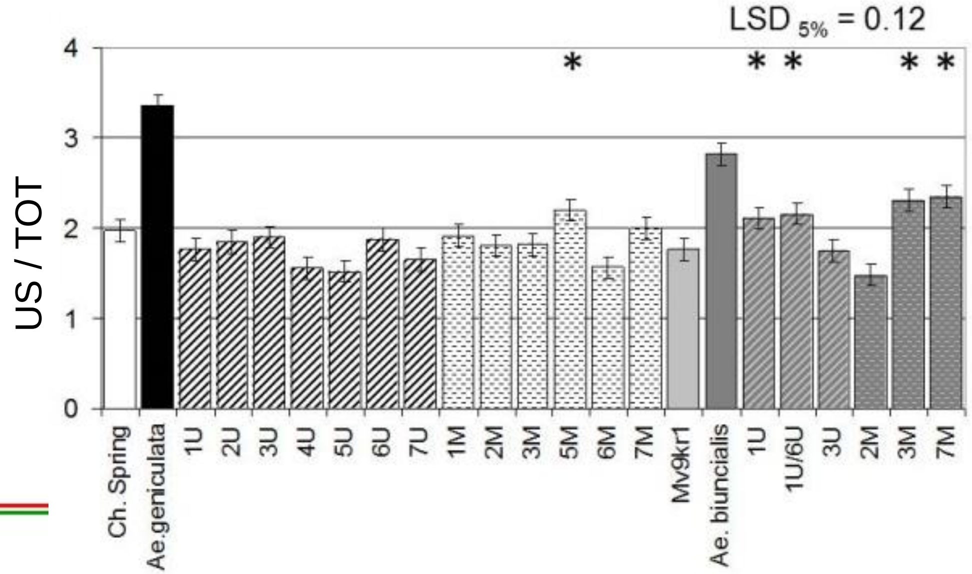


Effect of chromosome additions on the quantity of dietary fibers



Effect of chromsome additions on the composition of dietary fibers using HPAEC method





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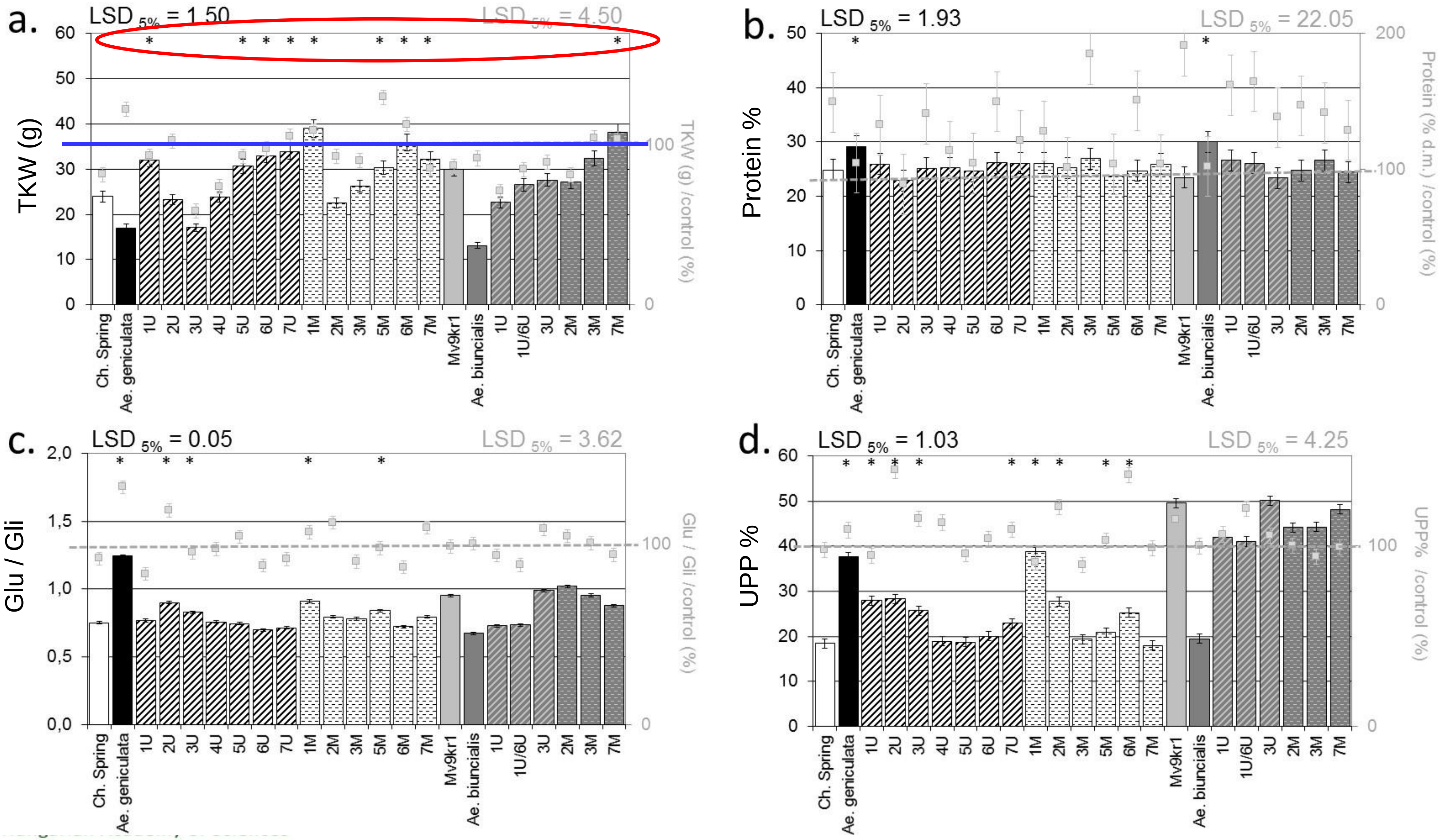
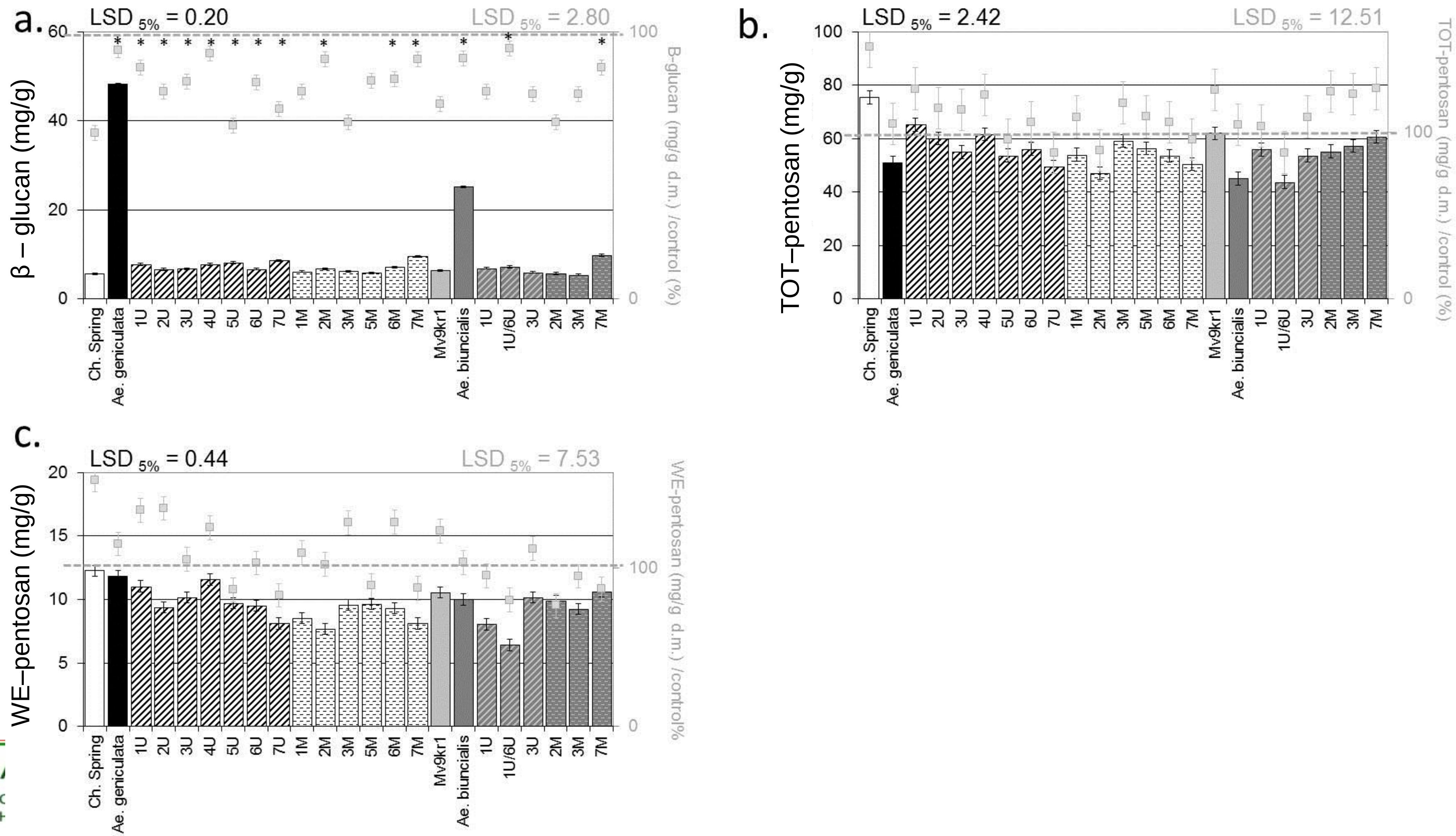
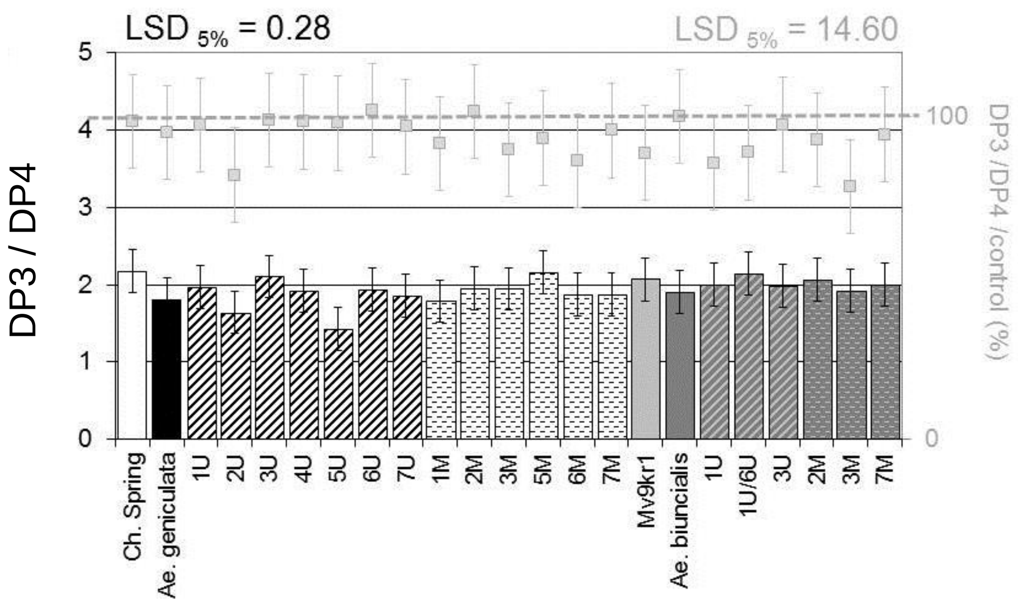
Effect of drought and chromosome additions on the protein characters

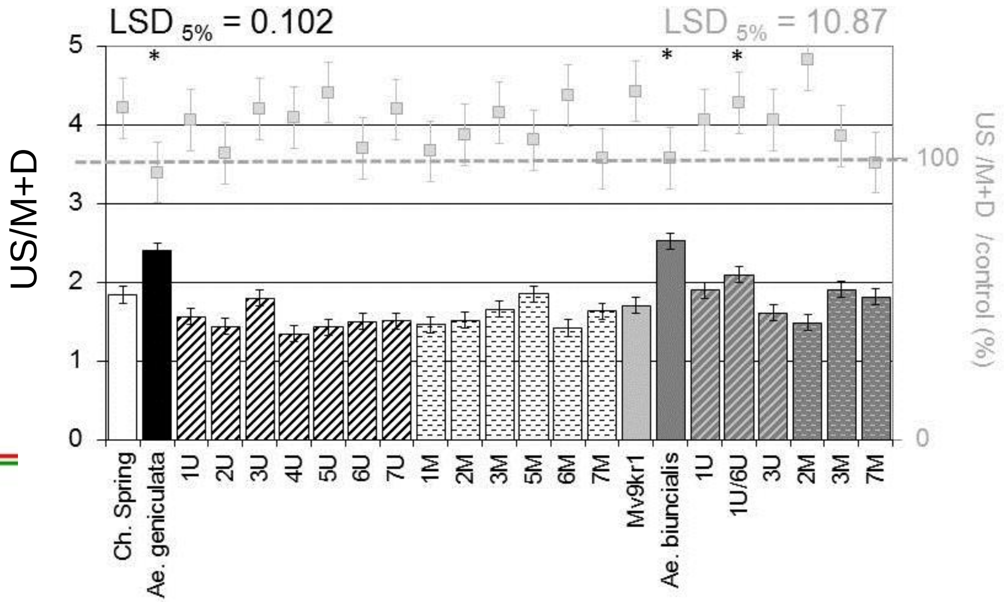


Effect of drought and chromosome additions on the fiber characters



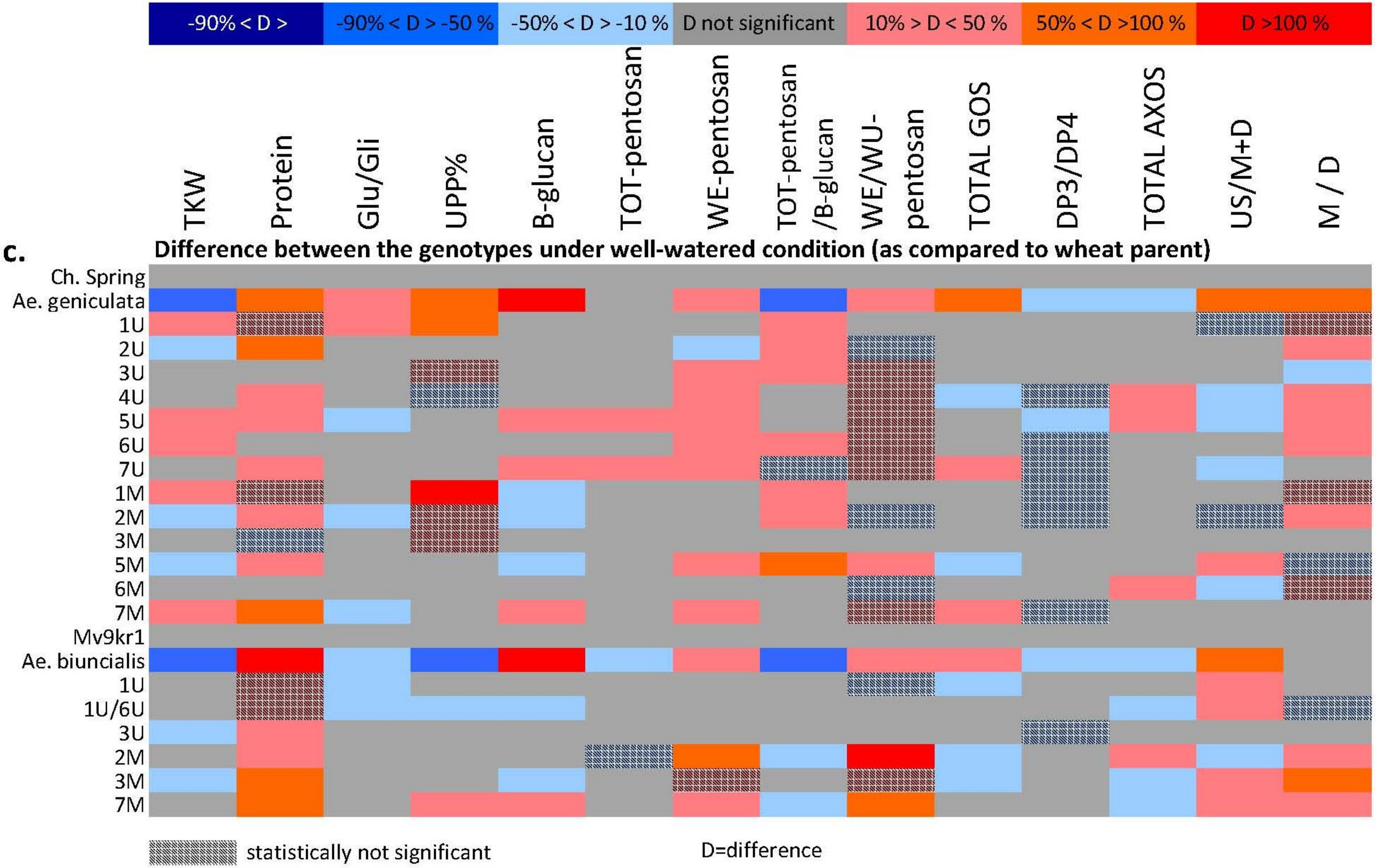
Effect of drought and the chromosome additions on the fiber composition by using HPAEC method





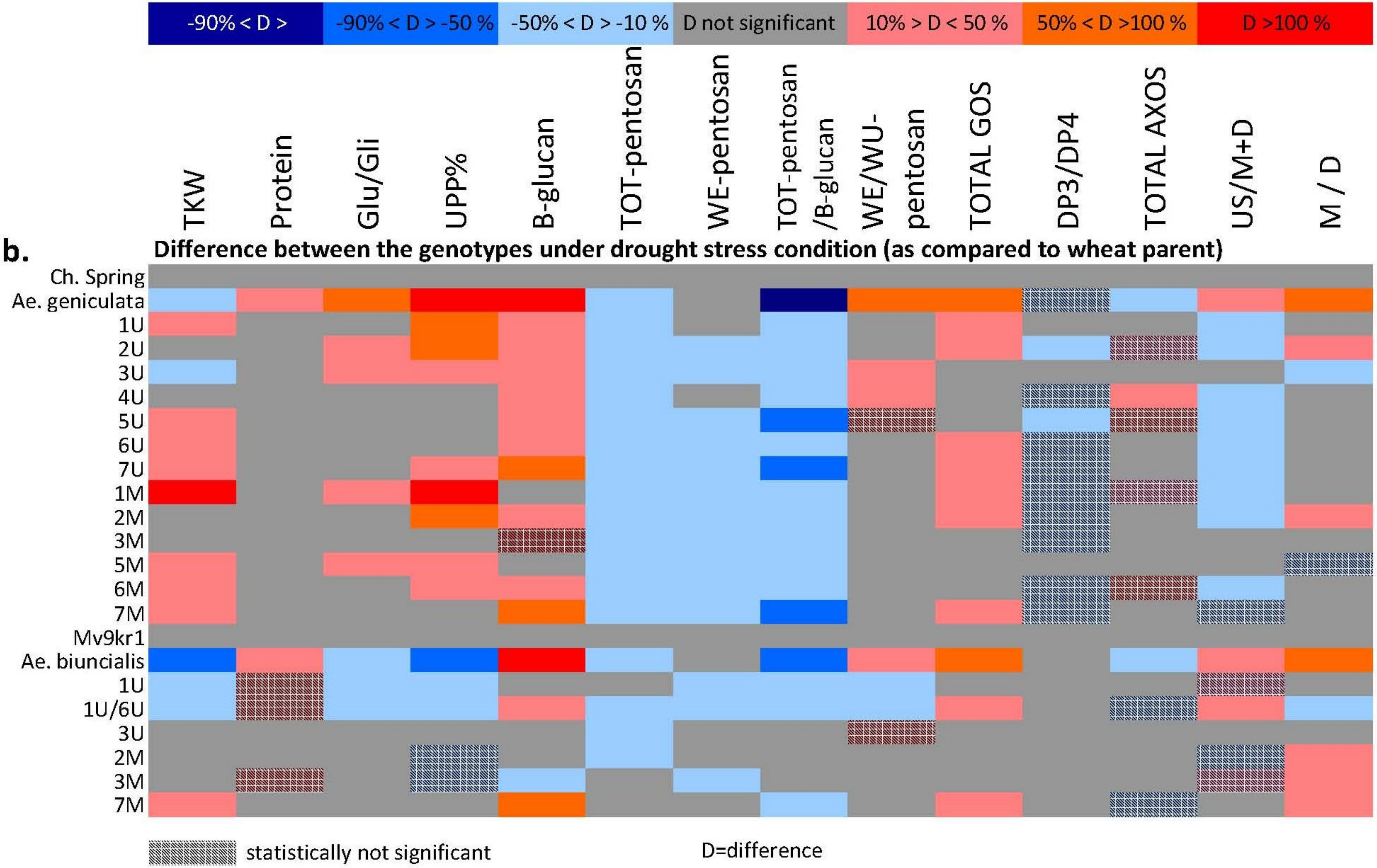
COLOUR MAP

Effect of chromosomes under control conditions



COLOUR MAP

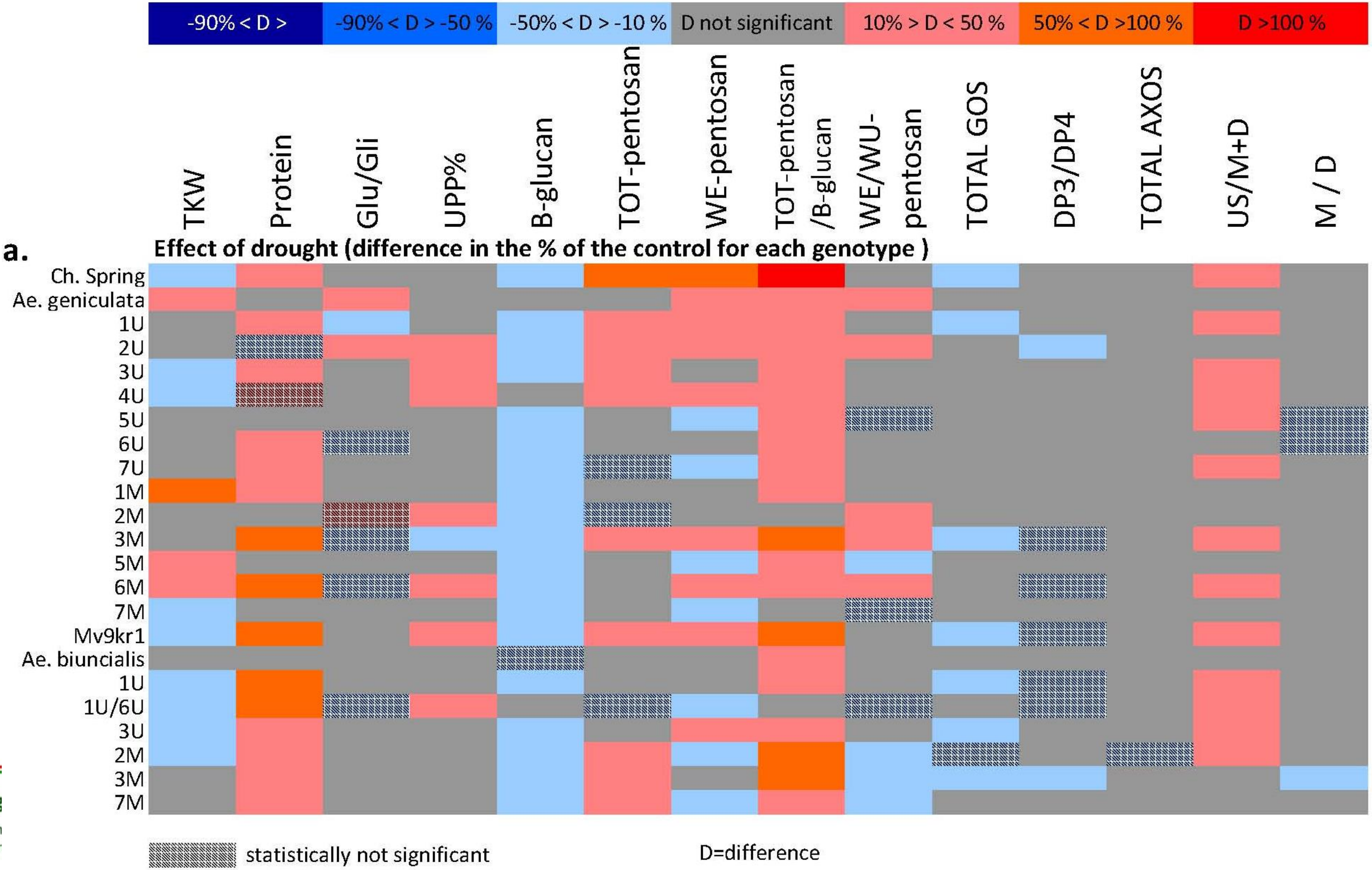
Effect of chromosomes under drought



Ag
Cen
Hun

COLOUR MAP

Effect of drought



Location of genes responsible for wheat storage protein biosynthesis in *Ae. umbellulata* U genome

Function	Gene	Accession No*	Chromosome	
Protein biosynthesis			*T. aestivum*	*Ae. umbellulata*
HMW glutenins	Glu-1Ax1	X61009	1A	1U
	Glu-1Ax2	M22208.2	1A	1U
	Glu-B1-1b	X13927.3	1B	1U
	Glu-1D-1d	X12928.5	1D	1U
	Glu-D1-2b	X12929.2	1D	1U
		X03041.1	1D	1U
	Glu-1Ux	AF476961.1	-	1U
	Glu-1Uy	AF476962.1	-	1U
LMW glutenins		AB062868.1	1D	1U
		AB062872.1	1D	1U
		JX163862.1	1B	1U
		HM055909.1	1DS	1U
		Y17845.1	1BS	1U
		U86026.1	1DS	1U
γ-gliadins	Group/Pattern/Subgroup			
	C10/C10-P1/SG-1	AJ937838.1	1DS	1U
	C9/C9-P2/SG-2	AF234646.1	1DS	1U
	C9/C9-P3/SG-3	FJ006638.1	1DS	1U
	C9/C9-P4/SG-4	FJ006605.1	1DS	1U
	C9/C9-P4/SG-6	AF234647.1	1BS	1U
	C9/C9-P4/SG-7	FJ006596.1	1DS	1U
	C8/C8-P5/SG-8	AF175312.1	1DS	1U
α-gliadins		AJ133612.1	6AS	1U
		DQ166377.1	6AS	1U
		K03074.1	2BS	1U
		M11075.1	6AS	1U, 2U
		U08287.1	6AS	1U, 3U
		X01130.1	6AS	1U, 3U
		U50984.1	6AS	1U, 3U
		X02539.1	6AS	1U, 3U

*: NCBI

Location of genes responsible for dietary fiber biosynthesis in *Ae. umbellulata* U genome

Function	Gene	Accession No*	Chromosome	
			T. aestivum	*Ae. umbellulata*
β-glucan biosynthesis	OsCslF1	AF432502.1	2AS, 2BS	2U
	OsCslF2	AF432503.1	2BL	2U
	HvCslF3	EU267179.1	2AS, 2BS, 2DS	2U
	HvCslF4	EU267180.1	2AS, 2BS	2U
	HvCslF6	EU267181.1	7DL	7UL
	HvCslF7	EU267182.1	5BL	5U
	HvCslF8	EU267183.1	2AS, 2BS, 2DS	2U
	HvCslF9	EU267184.1	1AS, 1BS, 1DS	1U
	HvCslF10	EU267185.1	2AS, 2BS, 2DS	2U
Arabinoxylan biosynthesis	TaGT43-2D	HF913567.1	4AS	4U
	TaGT43-2B	HF913568.1	4AS	4U
	TaGT43-2A	HF913569.1	4AS	4U
	TaGT43-4	HM236487.1	7AL, 7BL, 7DL	7UL
	TaGT47-2B	HF913570.1	3B	3U
	TaGT47-2D	HF913571.1	3AL	3U
	TaGT47-2A	HF913572.1	3AL	3U
	TaGT47-12	HM236486.1	3AL, 3B, 3DL	6U
	TaGT47-13	HM236485.1	3AL, 3B, 3DL	3U
	TaGT61-1	FR873610.1	1BL	6U
	TaGT61-2	FR846232.1	6AL	4U
	TaGT75-1	HM236488.1	2AL, 2BL, 2DL	2U
	TaGT75-4	HM236489.1	4AL, 4BS, 4DS	6U
	TaBAHD1A	Traes_3AS_75E04A7F4**	3AS	3U

*: NCBI;
**EnsemblPlants

Summary and conclusion

1. *Aegilops* had higher protein and β-glucan than wheat and the solubility of pentosans were also higher under control and drought conditions
2. Drought stress increased the protein and TOT-pentosan content and the soubility of AX in the addition lines, while the TKW and the β-glucan content decreased
3. The effect of chromosomes 5U, 7U and 7M on the β-glucan content, and $1U^g$, $1M^g$ on the TKW, Glu/Gli and UPP% was evident under both conditions
4. *Aegilops* parents could preserve their original compositional properties than wheat under drought, and this effect appeared in some wheat/*Aegilops* addition lines as well
5. Addition of $2U^g$, $3U^g$, $5U^g$, $7U^g$, $2M^g$, $5M^g$ and $7M^g$ chromosomes contributed to the stabilization of the protein and pentosan content
6. From these: $2U^g$ and $7U^g$ chromosomes mitigated the negative effect of stress on seed composition and physical properties as well
7. Results will contribute to the mapping of those *Aegilops* genomic regions that are responsible for dietary fiber content and composition.
8. The study will also contribute to the more efficient use of wild wheat relatives in alien introgression breeding programs to obtain wheat varieties with increased fiber content, especially b-glucan and improved health benefits, in general

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Rakszegi et al. 2017, Frontiers in Plant Science 8, 1529

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