The content of the microelements in DHL of CS x SQ1 under the two water regiments in South-East of Kazakhstan

Abugalieva A[1,5], Abugalieva S[2], Quarrie SA*[3], Cakmak I[4], Savin T[5], Turuspekov Y[2]
[1]Center for Crops Science and Farming, 37 Yerlepesov street, Almalybak 040909, Almaty region, Kazakhstan;
[2]Institute of Plant Biology and Biotechnology, National Center for Biotechnology, 45 Timiryazev street, Almaty, 050040, Kazakhstan;
[*]John Innes Centre, Norwich NR47UH, UK, [3]Current address: Kraljice Natalije 39, 11000 Belgrade, Serbia;
[4]Sabanci University, Faculty of Engineering and Natural Sciences6 Orhanli-Tuzla 34956, Turkey;
[5]Kazakh Agrarian University, 8 Abai street, Almaty, Kazakhstan

INTRODUCTION

The World Health Organization estimates that more than 2 billion people have deficiencies in key micronutrients such as Zn and Fe. The Fe deficiency in human can be reversed by providing balanced nutrient products, including from wheat grain. Kazakhstan is a large agricultural country with wheat growing on 11-13 mln hectares. However, the average level of Fe and Zn in modern wheat cultivars is relatively low[1, 2]. The problem can be solved by using modern genetic approaches based on identification of genes that control the regulation of nutrient content and grain quality[3]. A population of ninety-five wheat doubled haploid lines derived from the cross Chinese Spring x SQ1 was evaluated for the content of the microelements. The genetic material was analysed for Fe, Zn, and S on the background of K, P, Mg, Ca, Mn, Cu, and Al content in dryland and irrigated conditions.

MATERIALS AND METHODS

Ninety-five wheat doubled haploid lines from the cross between common wheat (*T. aestivum* L.) genotypes "Chinese Spring x SQ1" (CSDH lines) were tested in field experiments carried out in 1998, 1999, 2000, and 2005 at two experimental farms of the Center for Crops Science and Farming, Almaty region, under irrigated and non-irrigated conditions[4]**.** The map Chinese Spring x SQ1 consists of 567 RFLP, AFLP, SSR, morphological and biochemical markers covering all 21 chromosomes, with a total map length of 3522 cM[4]. The content of the microelements was detected on the Variance 330.

RESULTS AND DISCUSSION

The observation suggested that Fe content was ranged from 42 to 72 mg kg in dryland and from 40 to 70 mg kg in irrigated site; Zn content ranged from 35 to 56 mg kg in dryland and from 34 to 74 mg kg in irrigated site; S content varied from 1642 to 2160 mg kg in dryland and from 1522 to 2616 mg kg in irrigated site (table 1).

Table 1. Range of micro- and macro elements content in grain of 95 doubled haploid lines from the cross between common wheat (*T. aestivum* L.) genotypes "Chinese Spring x SQ1", grown in irrigated and rainfed conditions of Almaty region

	Irrigated conditions			Rainfed conditions		
	min	max	mean	min	max	mean
K	3611	5581	4502	3819	5949	4828
P	3839	6188	4919	4214	6088	4992
Mg	1096	1893	1545	1257	1941	1562
S	1522	2616	1954	1642	2160	1914
Ca	430	734	560	406	711	560
Fe	40	70	54	42	72	51
Mn	35	68	55	47	75	57
Cu	5	9	7	5	8	7
Zn	34	74	55	35	56	45
Al	7	32	14	8	23	13

Maximal content of S and Zn was higher in irrigated conditions than in rainfed site. In general, under irrigated conditions about 52% CSDH were characterized by iron content from 51 to 60 mg kg-^{1}, and more than 61 mg kg^{-1} was observed for 19% double haploid lines (Figure 1). These lines represents valuable material for biofortification, especially lines forming stable Fe content both under irrigated and rainfed conditions (the main areal of spring wheat growing in Kazakhstan): CSDH1 (70-60 mg kg^{-1}); CSDH3 (63-60 mg kg^{-1}); CSDH9 (63-61 mg kg^{-1}); CSDH41 (61-69 mg kg^{-1}); CSDH54 (67-60 mg kg^{-1}). Lines with high Fe content in grain, grown under irrigated conditions CSDH20 (69 mg kg-1); CSDH40 (72 mg kg^{-1}); CSDH44 (65 mg kg^{-1}); CSDH64 (65 mg kg^{-1}) и CSDH61 (64 mg kg^{-1}) considered to be perspective as intensive type. On the contrary, CSDH46 и CSDH41, characterized by high quantity of Fe in comparison to irrigated site (62 mg kg^{-1} and 69 mg kg^{-1}, respectively) were revealed under rainfed conditions. Stable low iron quantity in wheat flour was observed in the following double haploid lines: CSDH35 (45-47mg kg^{-1}), CSDH37 (46-47mg kg^{-1}), CSDH38 (40-45 mg kg^{-1}), CSDH51 (45-44 mg kg^{-1}), CSDH57 (46-48 mg kg^{-1}), and CSDH70 (42-45mg kg^{-1}).

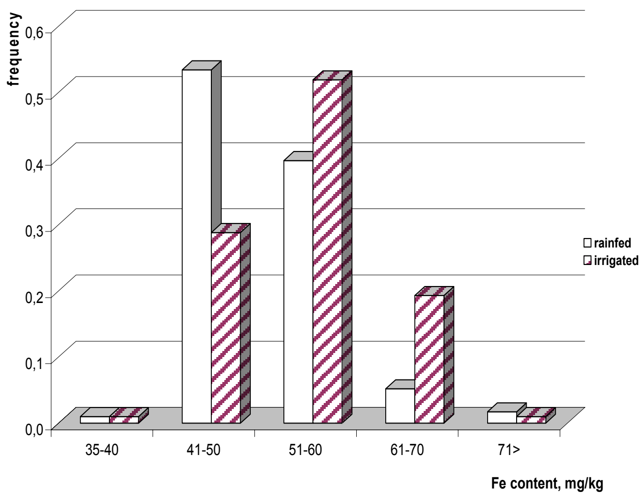

Figure 1. Fe content in grain of doubled haploid lines from the cross between common wheat (*T. aestivum* L.) genotypes "Chinese Spring x SQ1", grown under irrigated and rainfed conditions of Almaty region

Also 25% of CSDH grown under irrigated conditions had high quantity of zinc >61 mg kg^{-1} (Figure 2). It were revealed the CSDH with (i) stable high quantity of Zn (CSDH61 (72-52) and CSDH63 (62-52)), (ii) stable low content (CSDH38 (34-37)) and stable middle – CSDH5 (56-54 mg kg^{-1}), CSDH35 (57-51), and CSDH46 (52-55 mg kg^{-1}).

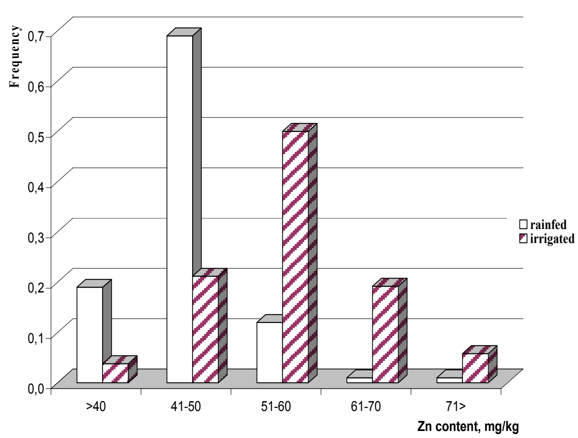

Figure 2. Zn content in grain of doubled haploid lines from the cross between common wheat (*T. aestivum* L.) genotypes "Chinese Spring x SQ1", grown in irrigated and rainfed conditions of Almaty region

Content of zinc in spring wheat grain grown under irrigated conditions prevailed the Zn quantity in rainfed conditions for CSDH1; CSDH3; CSDH20; CSDH44; CSDH60, and CSDH64 (65-70 mg kg^{-1}). Stable low content of Zn was observed for CSDH-38 (34-37 mg kg^{-1}), this line was occurred to have low content of Fe and protein as well.

Doubled haploid lines CSDH14, CSDH32, CSDH34, CSDH46 и CSDH94 corresponding to first ten ranks on Zn and Fe content in grain grown under rainfed conditions were also characterized by the most high gluten content; CSDH34 and CSDH63 – had the highest gluten quality; CSDH14, CSDH32, and CSDH34 – were occurred among the highest ten on sedimentation value; CSDH64 and CSDH46 – on amylose content (both in irrigated and rainfed conditions); CSDH64, CSDH105, and CSDH9 – on flour whiteness; CSDH94, CSDH32, CSDH56, and CSDH54 – on water absorption ability (table 2) [5].

Grain protein content (GPC) of common wheat *Triticum aestivum* L. is one of the important grain quality traits determining its nutritional and end-use value. The variations in protein content and composition significantly modify quality for bread-making[6, 7]. Although grain protein composition depends primarily on genotype, it is significantly affected by environmental factors and their interactions[8, 9]. In our study genotype-environmental interactions the protein content was determined by genotypes on 22%; environment – 6%, and their interactions – 72%. Lines characterized by not only max grain quality traits but their stability have significant value. CSDH47, CSDH28, CSDH61, CSDH90, CSDH96 have been revealed to be the most perspective on GPC.

The significant correlations were determined between contents of Zn и Fe (r=0,76); Zn and P (r=0,71); Fe and P (r=0,62); S and gliadin (r=0,54); Zn и protein (r=0,64). It is important to study the iron and zinc contents in crop plants and improve it by genetic means. The quantitative trait loci (QTLs) analysis suggested that genes determining the Fe, Zn, S, K, and Ca content located on the following chromosomes of the CS-SQ1 map: Fe – chr 2A (LOD 2.7); Zn – chr 3B (LOD 2.5); S – chr 7A (LOD 2.5); K- chr 4D (LOD 2.6); Ca – chr 4A (LOD 7.3). Genetic mapping of the existing variation in Fe and Zn content, GPC, hardness, and other traits will allow marker-assisted breeding to exploit the available natural variation in crop plants.

CONCLUSION

The range of iron and zinc content in grain CSDH mapping population has revealed to conduct QTL analysis for these traits and observe 5 QTLs for content of Fe (chr 2A, LOD 2.7), Zn (chr 3B, LOD 2.5), S (chr 7A, LOD 2.5); K (4D, LOD 2.6), and Ca (chr 4A, LOD 7.3). Correlations between Zn and protein content have been revealed. CSDH with stable high values of Fe and Zn content forming in grain under rainfed and irrigated conditions have been revealed. These lines are considered to be perspective for biofortification of spring wheat grain in Kazakhstan.

REFERENCES

1. Savin T, Abugalieva A, and Cakmak I, 2007. Characteristics of grain and flour of common wheat on Fe and Zn content. Research and results. 3:14-20. (*Kazakhstan's journal, paper in Russia*n)
2. Morgunov AI, Gomez-Becerra HF, Abugalieva AI, Dzhunusova M, Yessimbekova MA, Muminjanov H, Zelenskiy Y, Ozturk L, and Cakmak I, 2007. Iron and Zinc grain density in common wheat grown in Central Asia. Euphytica. 155:193-203.
3. Ghandilyan A, Vreugdenhil D, Aarts MGM, 2006. Progress in the genetic understanding of plant iron and zinc nutrition. Physiologia Plantarum. 126 (3):407–417.
4. Quarrie SA, Steed A, Calestani C, Semikhodskii A, Lebreton C, Chinoy C, Steele N, Pljevjakusic D, Waterman E, Weyen J, Schondelmaier J, Habash DZ, Farmer P, Saker L, Clarkson DT, Abugalieva A, Yessimbekova M, Turuspekov Y, Abugalieva S, Tuberosa R, Sanguineti M-C, Hollington PA, Aragues R, Royo A, and Dodig D, 2005. A high-density genetic map of hexaploid wheat (*Triticum aestivum* L.*)* from the cross *Chinese Spring x SQ1* and its use to compare QTLs for grain yield across a range of environments Theoretical and Applied Genetics. 110:865-880.
5. Abugalieva A, Abugalieva S, 2006. Quality of grain, flour, and bread in doubled haploid lines of common 10wheat. Biotechnology. 3:47-58. (*Kazakhstan's journal, paper in Russia*n)
6. Weegels PL, Hamer RJ, Schofield JD, 1996. Functional properties of wheat glutenin. Journal of Cereal Science 23: 1–18.
7. Branlard G, Dardevet M, Saccomano R, Lagoutte F, Gourdon J, 2001. Genetic diversity of wheat storage proteins and bread wheat quality. Euphytica 119: 59–67.
8. Triboi A, Martre P, Triboi-Blondel AM, 2003. Environmentally-induced changes in protein composition in developing grains of wheat are related to changes in total protein content. Journal of Experimental Botany. 54: 1731-1742.
9. Dholakia BB, Ammiraju JS, Santra DK, Singh H, Katti MV, Lagu MD, Tamhankar SA, Rao VS, Gupta VS, Dhaliwal HS, Ranjekar PK, 2001. Molecular marker analysis of protein content using PCR-based markers in wheat. Biochem Genet. 39:325-38.

Table 2. Doubled haploid lines from the cross between common wheat (*T. aestivum* L.) genotypes "Chinese Spring x SQ1", grown in irrigated and rainfed conditions of Almaty region with the maximal grain quality traits values

Rank	Gluten content		Gluten quality		Sedimentation		Amylose content		Fe, irrigated		Fe, rainfed		Zn, irr.		Zn, rainfed	
	CSDH	%	CSDH	U	CSDH	ml	CSDH	%	CSDH	mg kg^{-1}	CSDH	mg kg^{-1}	CSDH	mg kg^{-1}	CSDH	mg kg^{-1}
1	14	68,8	39	55	10	88	36	26,4	1	70	40	72	54	74	54	56
2	58	64,0	34	60	13	86	23	26,4	20	69	41	69	61	72	46	55
3	32	63,2	67	70	32	84	43	25,1	54	67	46	62	52	71	5	54
4	46	62,8	86	70	33	85	2	24,8	64	65	9	61	44	70	105	52
5	34	62,0	90	70	58	84	64	24,4	44	65	3	60	20	66	61	52
6	47	62,0	96	70	90	82	15	23,6	61	64	54	60	64	66	63	52
7	94	62,0	10	75	14	80	19	23,6	3	63	1	59	1	65	35	51
8	17	60,8	23	75	99	79	21	23,6	9	63	5	57	3	65	3	50
9	92	60	63	75	34	85	46	23,1	41	61	14	54	60	63	14	50
10	51	60	-	-	105	79	-	-	56	61	32	54	63	62	94	50