Genotype by environment and stability analysis for mineral concentrations in wild emmer (*Triticum dicoccoides*) accessions in Turkey and Israel

H F Gomez[1*], A Yazici[1], L Ozturk[1], H Budak[1], Z Peleg[2], Y Saranga[2], F Tzion[3], I Cakmak[1]

[1]Faculty of Engineering and Natural Sciences, Sabanci University, Istanbul, Turkey

[2]The RH Smith Institute of Plant Science and Genetics in Agriculture, The Hebrew University of Jerusalem, Rehovot, Israel

[3]Institute of Evolution, University of Haifa, Israel

*Presenting author

INTRODUCTION

Wild emmer (*Triticum dicoccoides*) has been reported to be an important genetic resource for the improvement of some important traits related with biotic and abiotic stresses in modern cultivated wheats. Also, it appears to be very promising for the improvement of the mineral content in the grain. Previous mineral seed concentration reports have been based on greenhouse experiments or at individual locations (Cakmak et al, 2004), and more recently, under different water regimes (Peleg et al, 2008). In the present study we aim to characterize a collection of wild emmer for macro and micro mineral concentration in seeds evaluated at different environments (different location/year combination) taking into account the genotype by environment interactions and the stability of the genotypes across the environments.

MATERIALS AND METHODS

A collection 21 genotypes (19 wild emmer and two *Triticum durum*) with balance data for the grain mineral concentration of 9 macro and micro minerals (P, K, Mg, S, Ca, Fe, Mn, Cu and Zn) grown at 6 different locations over 2-3 years (2005-7) in Turkey and Israel, was used to investigate for each mineral the (i) GxE interactions, (ii) genotypic stability, (iii) correlation among minerals, and (iv) mineral stability. Genotype x Environment (GxE) was evaluated by the AMMI model. Environment classification was done by cluster analysis (Ward's method) using the environmental PC scores. Genotype stability was conducted by the Finlay and Wilkinson' *b* stability coefficient. Associations between traits were established by correlation and principal component analysis, whereas the mineral stability among environment was done by linear regression technique.

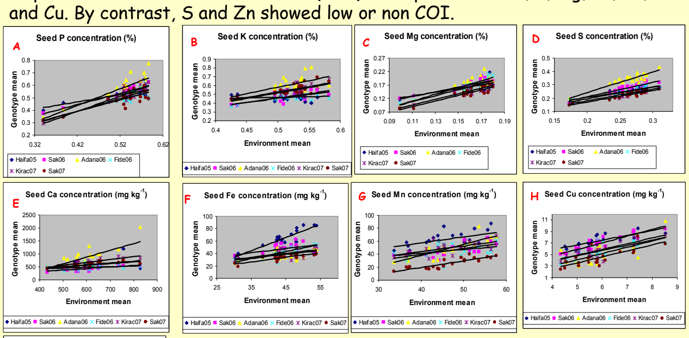
RESULTS

Large variation in the grain content of most of the macro and micro minerals was observed in the tested genotypes. Among the macro minerals Ca (range 288-2034 mg kg^{-1}), P (range 0.30-0.78%) and S (range 0.14-0.43%) showed the largest variation, whereas in the case of micronutrients, the largest variation was observed in the Zn concentration (range 23-115 mg kg^{-1}). Fe and Mn also showed important variation (range 19-86 and 13-87 mg kg^{-1}, respectively) (Table 1).

Table 1. Genotype mineral mean, the Finlay and Wilkinson' *b* stability coefficient and mineral mean and range for 21 emmer wheat and durum wheat genotypes evaluated at 6 environments during 2005-2007.

Code	Genotype	P (%)		K (%)		Mg (%)		S (%)		Ca (mg kg^{-1})		Fe (mg kg^{-1})		Mn (mg kg^{-1})		Cu (mg kg^{-1})		Zn (mg kg^{-1})	
		Genot mean	*b*	Genot mean	*b*	Geno mean	*b*	Geno mea	*b*	Geno mean	*b*	Geno mean	*b*	Genot mean	*b*	Gen Mea	*b*	Genot mean	*b*
G1	24-39	0.58	1.27	0.54	1.17	0.18	0.63	0.29	1.08	565	0.58	54	1.40	45	0.55	6	0.55	74	1.25
G2	18-39	0.58	1.64	0.51	1.02	0.17	0.53	0.28	1.04	624	0.96	43	1.18	50	0.77	7	0.86	65	1.10
G3	18-60	0.54	2.57	0.54	2.33	0.17	1.53	0.29	1.23	736	1.52	42	0.87	56	1.38	9	0.35	62	1.20
G4	33-48	0.58	0.19	0.58	0.80	0.18	0.64	0.28	0.66	756	0.57	44	0.72	54	0.89	5	1.08	71	1.42
G5	33-58	0.54	0.15	0.54	0.76	0.16	0.45	0.25	0.81	547	0.34	38	0.69	49	0.94	5	0.69	57	0.94
G6	19-1	0.59	3.12	0.55	2.23	0.17	1.79	0.31	1.50	829	3.51	48	0.62	58	0.58	7	0.83	59	0.65
G7	19-36	0.57	0.92	0.53	1.05	0.17	1.22	0.29	1.16	558	0.36	48	0.95	47	1.07	5	1.22	60	1.06
G8	KH 5/1	0.55	-0.05	0.53	0.81	0.17	1.02	0.29	0.92	564	1.59	50	1.84	34	0.81	6	1.73	65	1.21
G9	KH 5/3	0.53	0.38	0.52	0.88	0.16	0.29	0.27	1.09	605	0.38	48	1.53	43	1.20	5	0.91	62	1.43
G10	P 2/3	0.53	1.47	0.53	0.47	0.16	1.75	0.26	1.36	557	1.18	47	1.29	42	1.15	6	1.20	58	0.79
G11	MM 5/2	0.57	1.25	0.54	1.41	0.18	0.83	0.28	0.86	614	1.14	48	1.34	44	1.30	5	1.08	72	1.42
G12	MM 5/4	0.58	0.61	0.56	1.01	0.18	1.06	0.28	1.38	651	1.28	53	1.44	44	1.21	5	1.22	80	1.14
G13	16-34	0.53	1.02	0.54	1.37	0.16	1.08	0.28	0.94	655	1.05	45	0.77	37	0.90	7	1.08	55	0.76
G14	16-40	0.54	0.19	0.53	0.45	0.16	0.84	0.27	0.86	660	0.58	44	0.94	37	0.99	7	1.30	60	0.75
G15	9-72	0.51	1.16	0.50	1.06	0.15	1.49	0.26	1.18	614	1.04	44	0.85	50	0.87	4	0.72	66	0.87
G16	13-B-89	0.49	0.44	0.54	0.21	0.15	0.77	0.23	0.97	591	0.38	42	1.19	45	1.67	6	1.17	57	1.03
G17	12-2	0.53	1.06	0.50	1.11	0.16	0.48	0.24	1.10	518	0.94	43	0.97	52	1.20	6	1.23	69	1.08
G18	12-3	0.53	0.88	0.50	0.70	0.16	1.09	0.25	0.99	505	1.02	42	0.41	51	0.64	6	0.76	67	0.47
G19	12-4	0.53	1.62	0.51	1.66	0.16	1.44	0.25	1.32	610	2.18	42	1.13	56	1.10	6	1.42	71	1.07
G20	Sivevo*	0.34	0.38	0.43	0.22	0.10	0.81	0.18	0.28	481	0.16	30	0.37	37	0.67	5	0.75	32	0.60
G21	Inbar*	0.39	0.73	0.44	0.29	0.11	1.27	0.17	0.29	433	0.26	31	0.52	41	1.13	5	0.85	40	0.78
	Mineral mean	0.53		0.52		0.16		0.26		604		44		46		6		62	
	Max**	0.78		0.81		0.23		0.43		2034		86		87		11		115	
	Min**	0.30		0.36		0.08		0.15		288		19		13		2		23	

Important "cross-over" interactions (COI) were present for P, K, Mg, Ca, Fe, Mn and Cu. By contrast, S and Zn showed low or non COI.



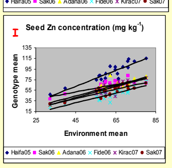
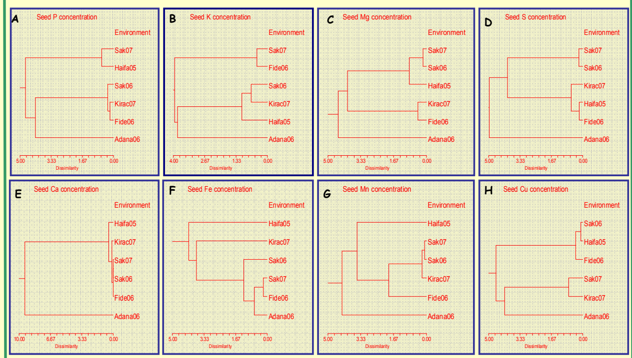


Figure 1. Graphical visualization of the GxE interactions per mineral. (A) P; (B) K; (C) Mg; (D) S; (E) Ca; (F) Fe; (G) Mn; (H) Cu; (I) Zn.

The Finlay and Wilkinson' *b* stability coefficient (Table 1) indicated that, in the case of Zn, genotype MM 5/4 was the most stable (mean of 80 mg kg^{-1} and stability *b* value of 1.14). Conversely, genotype 33-48 (mean concentration of 71 mg kg^{-1} and *b* value of 1.42), showed lesser adaptability, being only important in environments Haifa05 and Kirac07 (Table1)

Classification of environments: Environment Adana06 was the most discriminating environment for macronutrients, clustering apart from the rest of environments (Figure 2 A to E). In the case of micronutrients, environment Haifa05 consistently performed different from the rest of environments (Figure 2 F to I).



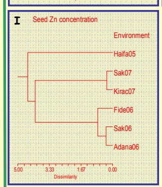


Figure 2. AMMI + Cluster analysis environmental classification per mineral. (A) P; (B) K; (C) Mg; (D) S; (E) Ca; (F) Fe; (G) Mn; (H) Cu; (I) Zn.

Important correlations were found between P and Zn (r = 0.55***), Zn and Fe (r = 0.78***). The correlation between Zn and S was not very high (r = 0.36) (Table 2).

The principal component analysis, suggested the possibility of a simultaneous improvement of Zn, Fe and Mn grain concentrations (Fig 3).

Table 2. Pearson correlation among grain Minerals concentrations from 21 wild emmer And durum wheat genotypes.

	Ca	Cu	Fe	K	Mg	Mn	P	S	Zn
Ca	1								
Cu	-0.09	1							
Fe	-0.10	0.56	1						
K	0.75	-0.25	-0.25	1					
Mg	0.36	0.31	0.48	0.35	1				
Mn	0.12	0.46	0.57	-0.20	0.43	1			
P	0.53	0.20	0.34	0.62	0.90	0.33	1		
S	0.53	0.16	0.29	0.47	0.78	0.28	0.78	1	
Zn	0.15	0.38	0.78	0.08	0.55	0.55	0.55	0.36	1

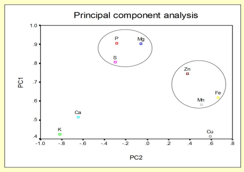


Figure 3. Principal component analysis of grain mineral concentrations in 21 wild emmer genotypes across six different environments

CONCLUSIONS

- Wild emmer showed important genetic diversity for grain mineral as Zn, Fe, S, and Mg, with existence of some outstanding genotypes with good stability and adaptability to different environments.
- Important cross-over interactions (COI) were observed in most of the minerals evaluated, however, S and Zn showed little level of COI.
- New genotypes 24-39 and 12-4 could have the potential to be considered as donors for the enhancement of Zn and Fe grain concentration as well.

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