Acta Alimentaria, Vol. 31 (3), pp. 235–242 (2002)

CONCENTRATION OF MACRO- AND MICROELEMENTS IN GRAIN OF SOME NEW WINTER WHEAT GENOTYPES (*TRITICUM AESTIVUM* L.)

M. SABO* and Ž. UGARČIĆ-HARDI

Faculty of Food Technology, J. J. Strossmayer University, F. Kuhača 18, 31000 Osijek. Croatia

(Received: 2 April 2001; accepted: 13 November 2001)

Mineral composition of grain of some new winter wheat genotypes in Croatia was studied. The following genotypes were selected: Lara, Lenta Kruna Fiesta, AG-45 and Perla which were taken from macrotrials during two vegetation periods of 1997/98 and 1998/99 at two locations in Donji Miholjac and Kutjevo. N-concentration was determined by the micro-Kjeldahl method, P spectrophotometrically and concentration of K, Ca, Mg, Zn, Cu, Fe and Mn by the AAS method (atomic absorption spectrophotometry). Interaction between the examined parameters was defined by multiple regression and correlation analysis. The results showed higher concentrations of N, P, K, Mg, Zn, Cu, and Mn, except for Fe, in the grain from Donji Miholjac than from Kutjevo. High concentration variability of macro and microelements in the grain of the examined genotypes depended on location and growing year. Concentration of macro and microelements in the grain did not have significant correlation with the grain yield for the examined genotypes, apart from N and Mg concentration.

Keywords: *Triticum aestivum* L, genotype, grain, macroelement, microelement

Adequate N supply of plants is specially important for crop yield and its quality. In addition to that, external factors influence it significantly, with their variability and impact intensity, plant growth and development, while the yield is determined by cultivar (namely, by genetic code), agroecological conditions and implemented techniques (VUKADINOVIĆ & LONČARIĆ, 1998). TEKLIĆ (1991) investigated correlation between mineral content of specific cultivars and wheat productivity and found significant positive correlation between grain yield and grain concentration of P, K and Ca. PETERSON and co-workers (1983; 1986) explored influence of location and cultivar on mineral content of a 60% extraction flour. High, genetically conditioned correlation between the protein content of the grain and concentration of Mg, P, Mn, Fe, Zn and Cu was noticed. Positive correlation between the protein content and concentration of Mg, P, Ca, Mn, Fe, Zn and Cu was found in flour. BEDE and co-workers (1997) found a significantly positive correlation between the grain number per ear and grain mass per ear. An increase of grain number raises the need for assimilates and this need can be met under favourable conditions of photosynthetic activity, while unfavourable conditions

* To whom correspondence should be addressed.
Fax: +385 31 207 115; e-mail: Mirjana.Sabo@ptfos.hr

0139-3006/2002/$ 5.00

result in premature translocation of assimilates from vegetative organs to the grain (SARIĆ, 1982). WALDERN and FLOWERDAY (1979) noticed that in addition to dry matter accumulation, more than 70% of total N, 75% of total P and only 15% of total K translocated to the grain during the wheat vegetation season. The biggest amounts of N, P, K, Ca, Mg, Fe, Cu, Zn and Mn were in the outer shell of the wheat grain and in the aleurone layer. Arrangement of certain elements in various parts of the wheat grain did not correspond with the arrangement of the total ash amount in the same parts of the grain (THOMAS & TUNGER, 1986). HACKENBERGER and co-workers (1987) examined mineral composition of the grain of 11 wheat varieties grown under identical agroecological conditions and discovered high variability of mineral content in the wheat grain, especially Ca, P, Cu, Fe and Zn which indicated that the composition was genetically conditioned. The objectives of the research were to establish differences among genotypes related to elementary composition of grain to investigate their productivity on the basis of elementary composition and structure yield.

1. Materials and methods

The research included six new genotypes of winter wheat: Lara, Lenta, Kruna, Fiesta, AG-45 and Perla taken from two locations, one near Donji Miholjac and the other in Kutjevo (Slavonia). It was done during two vegetation seasons in 1997/98 and 1998/99. The examined wheat genotypes differed concerning various characterisitics, but the biggest differences were in the grain yield. The average grain yield of the examined genotypes from both locations was the following: Lenta 9.7 t ha^{-1}, Perla 8.9 t ha^{-1}, Fiesta 8.4 t ha^{-1}, AG-45 8.1 t ha^{-1}, Kruna 8.0 t ha^{-1} and Lara 7.9 t ha^{-1}. The chosen locations differed in the height above sea level, chemical composition of the soil and climate. The height above sea level of Donji Miholjac is Hs=86 m, which is situated in the low-lying area, while Kutjevo is in the hilly area and its height above sea level is Hs=236 m. Differences in chemical composition of the soil (including fertilization scheme) are shown in Tables 1 and 2.

The average monthly temperatures in Donji Miholjac ranged from –0.3 °C (December 1997) and –1.1 °C (December 1998) to 20.8 °C (June 1998) and 21.3 °C (June 1999). In Kutjevo the temperatures ranged from –0.6 °C (December 1997) and –1.1 °C (December 1998) to 20.3 °C (June 1998) and 21.3 °C (June 1999).

Table 1. Results of soil analyses in the investigated localities

Localities	Soil analyses				
	pH H_2O	pH HCL	Humus %	P_2O_5	K_2O mg/100 g soil
Donji Miholjac	5.70	4.43	1.47	14.67	18.08
Kutjevo	7.10	6.03	1.47	30.56	15.82

Table 2. Fertilization in the localities during 1997/98 and 1998/99

Localities	Fertilization (kg ha^{-1}) 1997/98					Fertilization (kg ha^{-1}) 1998/99				
		N		P_2O_5	K_2O		N		P_2O_5	K_2O
	b.d.	t. d.	Σ	Σ	Σ	b.d.	t. d.	Σ	Σ	Σ
Donji Miholjac	107	82	189	67.5	52.5	126	68.5	194.5	67.5	52.5
Kutjevo	40	117	157	120	80	121	95	176	120	80

b.d.: basic dressing; t.p.: top dressing

However, the differences were more significant in precipitations than in temperatures. The average monthly rainfall in Donji Miholjac was 66.7 mm m^{-2} in December 1997 and in December 1998 it was 92.4 mm m^{-2}, while in Kutjevo it was 126.0 mm m^{-2} and 56.1 mm m^{-2}. In June 1998 the average rainfall in Donji Miholjac was 85.8 mm m^{-2} and 52.6 mm m^{-2} while in Kutjevo it was 158.0 mm m^{-2} and 52.6 mm m^{-2}. The average air humidity in Donji Miholjac in December 1997 and 1998 was 91% and 86% and in Kutjevo 94% and 93%. In June 1998 and 1999 the air humidity in Donji Miholjac was 67% and 66% and in Kutjevo 72% and 81%.

Sampling was done in the milk stage (June 1998 and 1999) to enable analysis of the grain mineral content. Twenty ears of each examined genotype were sampled in four repetitions (80 ears), and the wheat grain was dried at 105 °C, ground and mixed in an average sample. One gram of sample was destroyed by the wet procedure according to FALLER (1971) (10 ml of the mixture of c. H_2SO_4 and $HCLO_4$ (4:1) + 20 ml of conc H_2O_2, in the 30 min). Based on the obtained basic solution of each genotype, N concentration was determined according to the micro-Kjeldahl method, P by the spectrophotometric method (660 nm) and K, Ca, Mg, Fe, Cu, Zn and Mn by the AAS method. Grain yield was established due to the mass of twenty ears (four repetitions x 20 ears) and plant stand and expressed in t ha^{-1}.

The concentration data of the examined elements were obtained by chemical analysis, while mutual interdependence between the element concentration (N, P, K, Ca, Mg, Cu, Fe, Zn and Mn) and the grain yield was determined by multiple regression and correlation analysis. *F*-test was used to determine the significance of impact of a specific cultivar, mineral nutrition and agroecological factors of location.

2. Results and discussion

High variability of macro and microelements in the grain was established among the examined genotypes, locations and research years (Tables 3 and 4). The examined genotypes of 1998, contained, in average, higher concentrations of N, P, K and Mg at the location of Donji Miholjac compared to Kutjevo, except for Ca. Those of 1999 showed higher concentrations of macroelements at Kutjevo location compared to Donji Miholjac. In both research years the average concentrations of microelements of Zn, Cu and Mn, except for Fe, were higher in Donji Miholjac than in Kutjevo.

In 1998 the genotypes Lenta and Kruna had the highest percentage of N in the grain in Donji Miholjac, where the fertilization with N was better organized (higher amount in basic dressing and higher total amount of N, Table 2), while Lara, Lenta and Kruna had it in Kutjevo (containing, thus, the highest percentage of proteins). The N concentration of the genotype Kruna varied insignificantly in both years and locations. However, the other examined genotypes in 1999 showed significant differences in the concentration of N. More intensive allocation of N from vegetative parts of the plant to the grain in 1998 resulted in higher grain quality at both locations. Based on the results obtained it could be concluded that the concentration of N in the grain is a very specific cultivar characteristic (namely, the wheat quality regarding the protein amount) and it could be strongly influenced by the production year and location with its agro-ecological conditions. The concentration of P in the grain depended greatly on the genotype, location and production year. Phosphorous concentration of the grain was the highest in the genotype Perla in Donji Miholjac in 1998 but in Kutjevo it was the highest in Lenta and Perla. The lowest P concentration was in the genotype AG-45 at both locations (Table 3). In 1999 the highest P concentration was found in Lenta at both locations and the lowest in the genotype AG-45 (Table 4). More intensive translocation of P to the grain happened in 1999 in Donji Miholjac and Kutjevo, too, which differed from that of N (Table 3). According to TEKLIĆ (1991), location with its agroecological conditions, plays a significant role in the concentration of P.

Table 3. Average concentration of macro- and microelements in the grain of the examined winter wheat genotypes during 1997/98 (means ±SD)

Localities	N	P	K	Ca	Mg	Zn	Cu	Fe	Mn
Genotypes			%					mg kg^{-1}	
Donji Miholjac									
Lara	2.05	0.340	0.34	0.020	0.68	31.60	5.30	56.70	57.00
Lenta	2.27	0.301	0.29	0.021	0.67	34.90	5.65	61.40	73.80
Kruna	2.16	0.321	0.36	0.023	0.61	34.20	5.20	61.30	54.40
Fiesta	2.09	0.339	0.32	0.023	0.60	30.40	6.50	52.40	51.60
AG-45	2.03	0.293	0.32	0.022	0.58	38.80	8.40	63.30	66.00
Perla	2.08	0.361	0.27	0.020	0.69	32.40	8.90	58.30	56.00
Average	2.16±0.07	0.297±0.06	0.32±0.03	0.022±0.006	0.64±0.06	33.72±3.53	6.66±1.43	58.90±18.37	59.801±13.28
Kutjevo									
Lara	2.08	0.255	0.28	0.036	0.59	29.10	6.95	60.10	38.90
Lenta	2.07	0.316	0.29	0.033	0.64	29.50	5.70	61.70	48.30
Kruna	2.07	0.253	0.30	0.025	0.54	27.10	4.35	105.80	41.40
Fiesta	2.06	0.179	0.29	0.039	0.53	32.80	4.85	59.80	37.20
AG-45	2.04	0.201	0.32	0.027	0.54	26.00	4.65	106.75	28.50
Perla	2.03	0.316	0.35	0.030	0.59	32.80	6.20	61.60	36.00
Average	2.06±0.05	0.253±0.04	0.31±0.03	0.032±0.008	0.56±0.05	29.56±2.35	5.45±1.13	75.96±20.07	38.38±10.08

Table 4. Average concentration of macro- and microelements in the grain of the examined winter wheat genotypes during 1998/99, (means ±SD)

Localities Genotypes	N	P	K %	Ca	Mg	Zn	Cu	Fe mg kg^{-1}	Mn
Donji Miholjac									
Lara	2.18	0.313	0.30	0.01	0.50	30.50	9.05	45.15	86.00
Lenta	2.08	0.391	0.30	0.01	0.50	42.55	8.80	36.80	94.00
Kruna	2.16	0.353	0.33	0.01	0.46	36.50	8.90	38.80	80.50
Fiesta	1.65	0.263	0.31	0.01	0.44	36.85	8.60	40.70	102.00
AG-45	1.83	0.242	0.32	0.01	0.47	34.00	9.00	39.25	96.50
Perla	1.71	0.348	0.32	0.05	0.45	37.75	9.70	37.05	110.50
Average	1.94±0.19	0.271±0.04	0.31±0.01	0.02±0.02	0.47±0.02	36.36±4.89	9.00±1.11	39.63*±10.99	94.92±14.96
Kutjevo									
Lara	1.80	0.350	0.33	0.01	0.47	30.90	6.35	51.65	56.00
Lenta	2.13	0.367	0.32	0.01	0.50	41.15	7.05	67.20	72.50
Kruna	2.13	0.337	0.33	0.01	0.45	32.85	7.25	60.95	79.00
Fiesta	1.77	0.339	0.32	0.01	0.48	26.45	6.60	57.80	86.50
AG-45	1.89	0.297	0.33	0.01	0.46	31.50	7.20	57.75	86.00
Perla	2.06	0.332	0.31	0.01	0.49	29.05	8.30	60.05	103.50
Average	1.96±0.19	0.337±0.05	0.32±0.01	0.01±0.01	0.48±0.02	31.98±3.98	7.15±1.01	59.23±17.24	80.58±12.36

Potassium concentration was balanced in the grain for all examined genotypes at both locations and in both research years. Therefore, it could be assumed that conditions during grain filling were favourable for translocating K into the grain.

The average concentration of Ca in the grain of all examined genotypes was higher in Kutjevo than in Donji Miholjac (1998) (Table 3). According to KASTORI (1983) the ratio between K and Ca is very important for the harmonious nutrition of the plant and it could be assumed, therefore, that the genotypes of Kutjevo location absorbed Ca better.

Magnesium concentration in the grain depended greatly on the genotype and location in both research years (Tables 3 and 4). The obtained results were in accordance with many authors who emphasized the role of genetic specificity of the cultivar and climate conditions of the location. According to PETERSON and co-workers (1986), concentrations of N, Mg and P in the whole grain of wheat depended on the influence of location and cultivar. High variability of Cu, Fe, Ca, P and Zn concentration in the wheat grain (11 cultivars) under identical agroecological conditions was obtained by HACKENBERGER and co-workers (1987) indicating that grain composition is conditioned genetically. These researches showed high variability of microelements among the examined genotypes, between locations and production years. The biggest changes in Zn concentration were observed in Lenta at both locations and in 1998 and 1999, compared to other examined genotypes (Tables 3 and 4).

Concentration of Cu, Mn, and Fe (Tables 3 and 4) depended also on the genotype, location and research year. This corresponded with the results of PETERSON and co-workers (1983) proving that the concentration of microelements (Zn, Cu, Mn, Fe) in the whole wheat grain depended on location and cultivar.

In 1998 F-test has shown a very significant influence of genotype on the grain yield (F=19.726**), the impact of location (F=16.704**) and the interaction between genotypes and location (F=7.779**). This year there were no statistically significant correlations established between the concentrations of macro- and microelements and the grain yield. There was a positive correlation among most examined elements.

In 1999 F-test was used to determine very significant influence of genotypes (F=11.458**), location (F=8.851**) and interaction between genotypes and location (F=8.334**).

Concentrations of macro and microelements in 1999 did not significantly relate to the grain yield, except for the relation between N concentration (r=0.850**, P<0.01) (Fig. 1) and Mg (r=0.779**, P<0.01) (Fig. 2) and the grain yield, where high positive correlation was established. The other correlations were not statisitically significant. Cu concentration of the grain for all examined genotypes was in strong positive correlation with Fe concentration (r=0.780**, P<0.01) and Mn (r=0.731**, P<0.01), Mn concentration (r=0.712**, P<0.01) and Zn, as well as Mg concentration (r=0.830**, P< 0.01) and P, while mutual interdependence among the examined elements did not have statistically significant correlation.

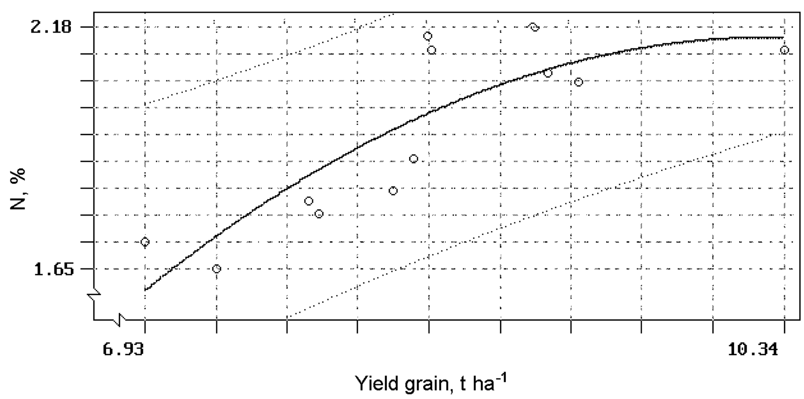

Fig. 1. Correlation between grain yield and N concentration in 1999, r=0.850**, $Y=-3.099916+1.022885 X + -4.974016E-02 X^2$

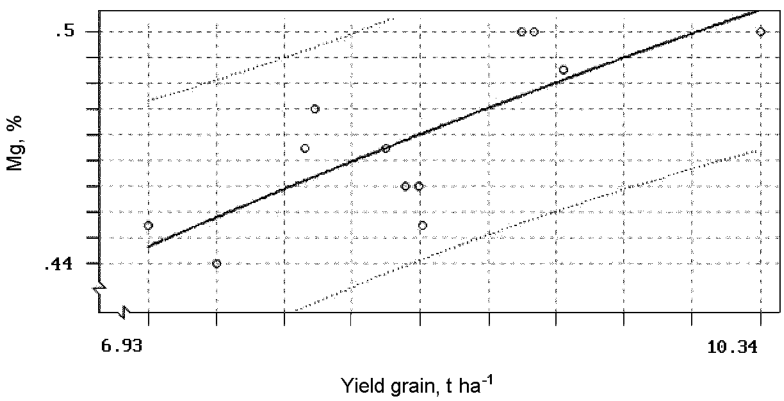

Fig. 2. Correlation between grain yield and Mg concentration in 1999, *r*=0.779**, Y=0.2738209 + 2.902503E-02 + –6.386247E-04 X^2

3. Conclusions

High variability of macro- and micorelements concentration in the grain of new winter wheat genotypes in the both years, depended on the genotype, locality and cultivation year.

Genotypes, Lenta, Kruna and Lara had higher grain percentage N compared to Fiesta, Perla and AG-45.

Concentration of K, Ca, and Mg were almost equal at both locations and in both research years. However, P concentrations also differed between the locations during research years. Zinc, Cu and Mn concentrations were regularly higher at Donji Miholjac locality whereas Fe at Kutjevo locality.

Concentration of macro- and microelements in the grain did not have significant correlation with the grain yield for the examined genotypes, apart from N and Mg concentration in 1999. The other correlations were not statisitically significant.

Copper concentration of the grain for all examined genotypes was in strong positive correlation with Fe concentration and Mn, Mn concentration and Zn, as well as Mg concentration and P, while mutual interdependence among the examined elements did not have statisitically significant correlations.

However, a very high correlation between Cu concentration and Fe and Mn concentration was determined. Also, a high correlation between Mn concentration and Zn concentration, as well between Mg concentration and P concentration was established.

References

BEDE, M., MARTINČIĆ, J. & MARIĆ SONJA (1997): Genetska varijabilnost komponenti uroda zrna AG-kultivara ozime pšenice. (Genetic component variability of grain yield of AG-cultivar of winter wheat.) Zbornik radova XXXIII znanstvenog skupa hrvatskih agronoma, (Proceedings XXXIII of Scientific Conference of Croatian Agronomists,) Pula 25-28.02. pp. 32–37.

FALLER, N. (1971): Razaranje biljnog materijala kombinirano vodikovim peroksidom i perklornom kiselinom. (Digestion of plant material using a mixture of hydrogen peroxide and perchloric acid.) *Agrohemija*, *13*, 293–300.

HACKENBERGER, D., CVIJOVIĆ, M. & BERTIĆ, B. (1987): Mineralni sastojci i kvaliteta različitih sorti ozime pšenice. (Mineral components and quality of various wheat varieties.) *Žito-hleb*, *14*, 231–239.

KASTORI, R. (1983): Uloga elementa u ishrani biljaka. (Role of elements in plant nutrition.) Lecture book, Department of natural sciences, Univesity of Novi Sad, pp. 107–111.

PETERSON, C. J., JOHANSON, Y.A. & MATTERN, P.J. (1983): Evolution of variation in mineral element concentrations in wheat flour and bran of different cultivars. *Cereal Chem.*, *60*, 450–455.

PETERSON, C. J., JOHANSON, Y.A. & MATTERN, P.J. (1986): Influence of cultivar and environment on mineral and protein concentrations of wheat flour, bran and grain. *Cereal Chem.*, *63*, 183–186.

SARIĆ, M. (1982): Genetska specifičnost mineralne ishrane biljaka. (Genetic specificity of mineral nutrition of plants.) Scientific assembles, Beograd, Vol. XIII, No. 3., pp 42–53.

TEKLIĆ, T. (1991): Korelativni odnosi između specifičnosti mineralne ishrane i produktivnosti pšenice. (Correlation between specificity of mineral nutrition and wheat yiled.) MA Thesis, J. J. Stossmayer University, Faculty of Agriculture, Osijek, pp. 58–67.

THOMAS, B. & TUNGER, D. (1986): Gewinnung vergleichbarer Richtwerte für den Mineralstoffgehalt in Weizen und Roggenmehlen. *Getreide & Mehl*, *4*, 29–34.

VUKADINOVIĆ, V. & LONČARIĆ, Z. (1998): Ishrana bilja. (Plant nutrition.) Lecture book, J. J. Strossmayer University, Faculty of Agriculture, Osijek, pp. 103–147.

WALDERN, R.P. & FLOWERDAY, A. D. (1979): Growth stage and distribution of dry matter N, P and K in winter wheat. *Agr. J.*, *71*, 391–397.