Scientific Papers. Series A. Agronomy, Vol. LXII, No. 1, 2019
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

MACRONUTRIENTS CONCENTRATION IN DURUM WHEAT VARIETIES GROWN AT DIFFERENT NITROGEN RATES

Galia PANAYOTOVA[1], Svetla KOSTADINOVA[2]

[1]Trakia University, Faculty of Agriculture, 6000, Stara Zagora, Bulgaria
[2]Agricultural University of Plovdiv, 12 Mendeleev Street, 4000, Plovdiv, Bulgaria

Corresponding author email: galia_panayotova@abv.bg

Abstract

The concentration of nitrogen, phosphorus and potassium in the grain and straw of seven Bulgarian durum wheat cultivars (Progress, Vazhod, Victoria, Predel, Deana, Zvezdica and Elbrus) in dependence on N rates 0, 60, 120 and 180 kg.ha^{-1} was studied in a field experiment with cotton-durum wheat crops rotation during the period 2010-2014 under non-irrigation conditions. It was established that rates N120 and N180 significantly increased N concentration of the wheat grain. Strong genotypic response of durum wheat to the grain N concentration was obtained in non-fertilized plants with variation from 1.96% N (Vazhod) to 2.40% N (Zvezdica). Predel and Zvezdica varieties showed higher grain N content. Newer varieties (Victoria, Predel, Deana, Zvezdica and Elbrus) were characterized with higher N concentration of the straw. N rates 0-180 kg N.ha^{-1} slightly changed the phosphorus concentration in the wheat grain (0.58-0.61% P_2O_5) and in the straw (0.10-0.19% P_2O_5). Deana and Vazhod varieties had higher grain phosphorus concentration when they were grown without fertilization, whereas Zvezdica variety was exceeded other varieties at rates N120 and N180. Predel and Zvezdica varieties showed higher potassium concentration of the grain.

Key words*: concentration of macronutrients, nitrogen, durum wheat.*

INTRODUCTION

The agrochemical evaluation of cultivars and hybrids was established as a compulsory part of modern breeding for high productivity of cereals in the last years (Sylvester-Bradley & Kindred, 2009). The newer genotypes of durum wheat have higher productive potential but they realize it after greater nutrient input (Johnson, 2004). Grain quality is the most important criterion in the breeding of durum wheat to produce high quality pasta (Ammes et al., 2003; Uppal et al., 2002). The new genotypes combine high productivity with good quality (Panayotova & Valkova, 2010; Rharrabti et al., 2003). Many studies have been conducted to examine the effects of nitrogen fertilizers and preceding crops on cereal grain yield. Some authors (Bauer et al., 1987; Carcea, 2003; Kostadinova, 2000) reported that the increasing nitrogen rate and rich soil fertility enhanced the content of grain protein and nitrogen in the straw. The responsiveness of different cultivars to nitrogen accumulated in the vegetative plant parts was established (May et al., 2008; Panayotova, 2010). Panayotova (2001) appoints a genotype specific in relation with grain yield depending on the nutrition level. Fertilizing effectiveness of varieties with different genetic traits under different soil fertility was established (Hawkesford, 2012; López-Bellido & López-Bellido, 2001; Mohammadi & Amri, 2009; Panayotova, 1999). Durum wheat requires optimum fertilizer rates, consistent with the conditions of the area and the specifics of the field to increase the grain quality (Panayotova & Gorbanov, 1999). Nitrogen has a strong influence on growth, but its impact on yield, quality and dry matter formation depends on the growing conditions. In meteorological terms, the favorable years strongly manifest the effect of higher nitrogen rate (Panayotova & Yanev, 2001; Rharrabti et al., 2003). The main requirement for good quality of the grain is for the plant to obtain the optimal nitrogen amount during vegetation (Fixen, 2009). The interaction between environmental conditions and nitrogen rates has a significant impact on grain quality (Sanjeev et al., 2000). Most research on wheat fertilization refers mainly to common wheat and only a limited number of them are on durum wheat, though not to the present-day most widespread intensive

varieties. The aim of this study was to investigate the effect of nitrogen fertilization rates on the concentration of macronutrients nitrogen, phosphorus and potassium in the grain and straw of new Bulgarian durum wheat varieties.

MATERIALS AND METHODS

The concentration of nitrogen, phosphorus and potassium in the grain and straw of seven Bulgarian durum wheat cultivars (Progress, Vazhod, Victoria, Predel, Deana, Zvezdica and Elbrus) in dependence on nitrogen rates 0, 60, 120 and 180 kg $N.ha^{-1}$ was studied in a field experiment with cotton – durum wheat crop rotation during the period 2010-2014, at the Field Crops Institute - Chirpan, Bulgaria, under non-irrigation conditions. The experimental design consisted of a randomized block design with four replications. The harvested size of the plots was 10 m^2. Nitrogen fertilization in the form of NH_4NO_3 was applied before sowing (1/3 of the rate) and at early spring (2/3 of the rate). The phosphorus fertilization (P_{80}) was done before sowing in the form of triple superphosphate. The precursor crop was cotton fertilized by N_{80}.

The soil type of the experimental field was *Pellic vertisols* (FAO), generally referred to as the so called Mediterranean chernozems. The soil type is one of the most generous and widely spread and significant in Bulgaria. It is suitable for growing most of the field crops and has a potential for high yield. The main parent materials were pliozen clay deposits. It has a high-powered humus horizon (70–80 cm), with a compact zone of the profile (united horizon). By humus content it belongs to the mean humus soils. It characterizes with high humidity capacity, caused by the high percentage of clay minerals, with clay soil texture, small water-permeability, bulk density of the arable soil layer 1.2-1.3 $g.cm^{-3}$, with specific gravity 2.4-2.6 and low total porosity, neutral soil reaction and high cation exchange capacity (CEC) 35-46 meq per 100 g soil, with a high degree of bases saturation (93.4-100.0%), with total N in the arable layer ranging within 0.095-0.14% and low content of total phosphorus (0.05-0.11%), poor to medium supplied with hydrolyzed nitrogen, poorly supplied with available phosphorus and well-supplied with available potassium.

Regarding the temperature during durum wheat vegetation, one of the experimental years was characterized as very warm, two as hot and two with values close to the multi-annual rate. In terms of precipitation, two years were dry and in the three harvest years the rainfall values ware close to the norm.

The concentration of nitrogen, phosphorus and potassium were analyzed in the grain and straw of wheat cultivars. The samples of 0.5 g ground and dry plant material were mineralized using a wet digestion by H_2SO_4 and H_2O_2 as a catalyst (Mineev, 2001). The concentration of nitrogen and phosphorus in plant samples were determined by colorimetric methods and potassium concentration was analyzed by flame photometer model PFP-7 (Tomov et al., 2009).

The data were statistically analyzed with the ANOVA procedure within the SPSS statistical program and Duncan's multiple range test ($P = 0.05$) to find significant differences among means.

RESULTS AND DISCUSSIONS

Nitrogen concentration in durum wheat grain is the main quality indicator for durum wheat (Uppal et al., 2002). According to Klimashevskiy (1990) genotypic differences are well-expressed in the zone of deficient and moderate mineral nutrition. Other researchers found that at high nitrogen levels, the genotypic differences in the percentage of nitrogen in the wheat grain were large and associated with differences in distribution of grain nitrogen, whereas at low nitrogen levels the variation was very low and dependent on the presence of nitrogen in the soil to the anthesis (Ortiz-Monasterio et al., 1997).

The average nitrogen content in the grain of wheat varieties grown at four levels of nitrogen fertilization ranged from 2.18% N to 2.72% N (Table 1). Nitrogen rates N_{120} and N_{180} increased the nitrogen concentration of the grain, whereas the effect of applied low rate N_{60} was not significant compared to N_0 control. Genotypic response was more pronounced in non-fertilized plants where the nitrogen concentration significantly changed from 1.96% N (Vazhod) to 2.40% N (Zvezdica).

Predel and Zvezdica varieties were characterized by higher N content in the grain without nitrogen fertilization and at low rate N_{60}, as well as an average of the studied N levels.

The highest concentration of grain nitrogen was obtained in Vazhod variety (2.89% N) fertilized with N_{180}. The N concentration of the straw of studied varieties ranged from 0.36% N (Progress at N_0) to 0.97% N (Predel & Zvezdica at N_{180}) (Table 1). Nitrogen fertilization increased the average nitrogen concentration of the straw - from 0.56% N in the non-fertilized varieties to 0.73-0.78% N in the fertilized plants. The results showed no proven differences in the average nitrogen content of the straw at rates N_{60}, N_{120} and N_{180}. Older Progress and Vazhod varieties demonstrated lower straw nitrogen concentration (below 0.60% N on average) compared to newer Victoria, Predel, Deana, Zvezdica and Elbrus varieties.

The average concentration of phosphorus in the grain of the studied wheat varieties was changed within a narrow range of 0.58-0.61% P_2O_5 depending on nitrogen fertilization in the rates of 0-180 kg $N.ha^{-1}$ (Table 2). The genotypic specificity of the concentration of phosphorus in the grain of wheat varieties was established. On average, for the studied nitrogen rates, Zvezdica variety showed the highest grain phosphorus content of 0.65% P_2O_5, while Progress and Elbrus varieties showed lower values of 0.54-0.56% P_2O_5. The Deana and Vazhod varieties were characterized with higher grain phosphorus concentration when were grown without fertilization, whereas the Zvezdica variety was exceeded other varieties at rates N_{120} and N_{180}. The studied durum wheat varieties demonstrated a low phosphorus concentration in the straw, which changed within a narrow range of 0.10-0.19% P_2O_5. Nitrogen fertilization with 120 and 180 kg $P_2O_5.ha^{-1}$ increased the average phosphorus content of the wheat straw. The average phosphorus concentration in the straw of durum wheat slightly depended on genotype.

Potassium concentration of the grain of the durum wheat changed from 0.16% K_2O (Vazhod at N_{180}) to 0.32% K_2O (Predel at N_{60}) (Table 3). The higher nitrogen rate N_{180} decreased the average potassium content of wheat grain compared to that of the plants grown without nitrogen and the plants fertilized with lower rate N_{60}. The genotypic reaction of durum wheat to the grain potassium concentration was proven.

Table 1. Nitrogen concentration of durum wheat varieties (N, %)

Variety \ Nitrogen rates	N_0	N_{60}	N_{120}	N_{180}	Average
Grain					
Progress	2.29 b	2.32 ab	2.50 c	2.55 d	**2.42 b**
Vazhod	1.96 f	1.95 e	2.26 d	2.89 a	**2.26 d**
Victoria	2.19 c	2.28 bc	2.65 b	2.62 cd	**2.43 b**
Predel	2.32 b	2.39 a	2.68 b	2.81 ab	**2.55 a**
Deana	2.08 d	2.07 d	2.52 c	2.64 c	**2.33 c**
Zvezdica	2.40 a	2.43 a	2.65 b	2.75 b	**2.56 a**
Elbrus	2.03 e	2.21 c	2.76 a	2.77 b	**2.44 b**
Average	**2.18 b**	**2.24 b**	**2.58 a**	**2.72 a**	
Straw					
Progress	0.36 d	0.66 cd	0.64 ef	0.68 bc	**0.58 c**
Vazhod	0.43 c	0.61 d	0.60 f	0.72 b	**0.59 c**
Victoria	0.63 b	0.69 c	0.68 de	0.65 c	**0.66 bc**
Predel	0.62 b	0.82 a	0.94 a	0.97 a	**0.83 ab**
Deana	0.44 c	0.69 c	0.73 cd	0.74 b	**0.65 c**
Zvezdica	0.82 a	0.87 a	0.84 b	0.97 a	**0.87 a**
Elbrus	0.64 b	0.75 b	0.74 c	0.75 b	**0.72 abc**
Average	**0.56 b**	**0.73 a**	**0.74 a**	**0.78 a**	

**Values in each column followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test.*

Table 2. Phosphorus concentration of durum wheat varieties (P_2O_5, %)

Variety \ Nitrogen rates	N_0	N_{60}	N_{120}	N_{180}	**Average**
Grain					
Progress	0.60 bc	0.54 c	0.45 d	0.57 c	**0.54 e**
Vazhod	0.63 ab	0.49 cd	0.66 ab	0.53 d	**0.58 cd**
Victoria	0.47 e	0.74 a	0.60 c	0.58 c	**0.60 bc**
Predel	0.60 c	0.60 b	0.64 abc	0.62 b	**0.61 b**
Deana	0.63 a	0.47 d	0.62 bc	0.64 b	**0.59 bc**
Zvezdica	0.60 bc	0.64 b	0.67 a	0.70 a	**0.65 a**
Elbrus	0.52 d	0.42 e	0.65 ab	0.63 b	**0.56 de**
Average	**0.58 ns**	**0.56**	**0.61**	**0.61**	
Straw					
Progress	0.10 c	0.10 b	0.14 bc	0.17 a	**0.13 ns**
Vazhod	0.10 c	0.11 b	0.14 bc	0.15 bc	**0.12**
Victoria	0.10 c	0.15 a	0.19 a	0.13 c	**0.14**
Predel	0.13 b	0.10 b	0.12 c	0.14 cd	**0.12**
Deana	0.10 c	0.11 b	0.18a	0.16 ab	**0.14**
Zvezdica	0.15 ab	0.15 a	0.15 b	0.14 cd	**0.15**
Elbrus	0.16 a	0.15 a	0.15 b	0.16 ab	**0.16**
Average	**0.12 b**	**0.12 b**	**0.15 a**	**0.15 a**	

**Values in each column followed by the same letters are not significantly different at p<0.05 according to Duncan's multiple range test.*

Table 3. Potassium concentration of durum wheat varieties (K_2O, %)

Variety \ Nitrogen rates	N_0	N_{60}	N_{120}	N_{180}	Average
Grain					
Progress	0.27 b	0.23 d	0.22 b	0.19 d	**0.23 c**
Vazhod	0.29 a	0.30 b	0.25 a	0.16 e	**0.25 b**
Victoria	0.23 c	0.28 c	0.22 b	0.22 c	**0.24 b**
Predel	0.30 a	0.32 a	0.22 b	0.27 a	**0.28 a**
Deana	0.22 cd	0.31 ab	0.22 b	0.23 bc	**0.24 b**
Zvezdica	0.29 a	0.28 c	0.26 a	0.23 b	**0.27 a**
Elbrus	0.21 d	0.21 e	0.19 c	0.19 d	**0.20 d**
Average	**0.26 ab**	**0.28 a**	**0.23 bc**	**0.21 c**	
Straw					
Progress	1.03 f	1.16 b	1.20 d	1.39 c	**1.20 b**
Vazhod	1.24 e	1.31 ab	1.86 a	1.90 a	**1.58 a**
Victoria	1.69 a	1.21 ab	1.64 b	1.05 d	**1.40 ab**
Predel	1.37 d	1.33 a	1.68 b	1.45 c	**1.46 ab**
Deana	1.43 c	1.32 ab	1.42 c	1.71 b	**1.47 ab**
Zvezdica	1.62 b	1.34 a	1.61 b	1.73 b	**1.58 a**
Elbrus	1.23 e	1.26 ab	1.41 c	1.37 c	**1.32 ab**
Average	**1.38 ab**	**1.27 b**	**1.55 a**	**1.51 ab**	

**Values in each column followed by the same letters are not significantly different at p<0.05 according to Duncan's multiple range test.*

Predel and Zvezdica varieties were characterized by a higher average potassium concentration in the grain. Progress and Elbrus varieties showed lower average potassium concentration in the grain, and the other three Vazhod, Victoria and Deana varieties were occupied an intermediate position.

The percentage of potassium in the straw of durum wheat was nearly six times higher than that in the grain. It changed to a wider range of 1.03% K_2O (Progress at N_0) to 1.90% K_2O (Vazhod at N_{180}). Genotypic differences in the average potassium content of the straw were significant between Vazhod and Zvezdica varieties (0.58% K_2O) and Progress variety (1.20% K_2O).

Positive and negative correlations between examined parameters of durum wheat were recorded in the study (Table 4). Nitrogen fertilization was highly positively correlated with the concentration of nitrogen in the grain (r = 0.812**).

Also, a positive significant correlation was achieved between the nitrogen fertilization rates and concentration of nitrogen (r = 0.518**) and phosphorus (r = 0.514**) in the straw. A positive relationship was established between grain nitrogen concentration and the concentration of nitrogen, phosphorus and potassium in the straw. Nitrogen fertilization in rates from 0 to 180 kg $N.ha^{-1}$ was negatively correlated with concentration of potassium in the grain of durum wheat varieties.

Table 4. Correlation among nitrogen fertilization rates, concentration of nitrogen, phosphorus and potassium in grain and straw of durum wheat

Parameters	% N grain	% P_2O_5 grain	% K_2O grain	% N straw	% P_2O_5 straw	% K_2O straw
N fertilization	0.812**	0.220	-0.510**	0.518**	0.514**	0.341
% N grain		0.356	-0.498**	0.620**	0.519**	0.407*
% P_2O_5 grain			0.109	0.225	0.201	0.232
% K_2O grain				-0.044	-0.459*	-0.249
% N straw					0.379*	0.403*
% P_2O_5 straw						0.284

***Correlation is significant at the 0.01 level*

**Correlation is significant at the 0.05 level*

CONCLUSIONS

Nitrogen rates N_{120} and N_{180} significantly increased average nitrogen concentration of the wheat grain, whereas the effect of lower rate N_{60} was not significant compared to N_0. Strong genotypic response of durum wheat to the grain nitrogen concentration was obtained in non-fertilized plants with variation from 1.96 % N (Vazhod) to 2.40% N (Zvezdica). Predel and Zvezdica varieties showed higher grain nitrogen content. Newer varieties (Victoria, Predel, Deana, Zvezdica and Elbrus) were characterized with higher N concentration of the straw. N rates 0-180 kg $N.ha^{-1}$ slightly changed the concentration of phosphorus in the wheat grain (0.58-0.61% P_2O_5) and in the straw (0.10-0.19% P_2O_5). Deana and Vazhod varieties had higher grain phosphorus concentration when they were grown without fertilization, whereas Zvezdica variety was exceeded other varieties at rates N_{120} and N_{180}. The average phosphorus concentration in the straw of durum wheat slightly depended on genotype. The higher nitrogen rate N_{180} decreased the average potassium content of wheat grain compared to that of plants grown without nitrogen and plants fertilized with lower rate N_{60}. Predel and Zvezdica varieties showed higher average potassium grain concentration. The potassium percentage in the straw of durum wheat was nearly six times higher than that in the grain and it was changed to a wider range of 1.03% K_2O (Progress at N_0) to 1.90% K_2O (Vazhod at N_{180}). Nitrogen fertilization was highly positively correlated with the grain nitrogen concentration (r = 0.812**) and it was negatively correlated with the concentration of potassium in the grain.

REFERENCES

Ammes, N. P., Clark, J. M., Dexter, J. E., Woods, J., Schols, F., Marchylo, B. (2003). Effects of nitrogen fertilizer on protein quantity and gluten streng parameters in durum wheat (*Triticum turgidum* L. var. *durum*) cultivars of variable gluten strength. *Cereal Chemistry, 80*, 203–211.

Bauer, A., Frank, A., Black, A. (1987). Aerial parts of hard red spring wheat. II. Nitrogen and phosphorus concentration and content by plant development stage. *Agron. J*., *79*, 852–858.

Carcea, M. (2003). The quality of durum wheat in Italy. *Sementi Elette*., *49*. 14–15.

Fixen, P. (2009). Nutrient Use Efficiency in the Context of Sustainable Agriculture, In J. Espinosa and F.

García (Eds.), Nutrient Use Efficiency, *International Plant Nutrition Institute* (IPNI), USA, 1–10.

Gastal, F., Lemaire, G. (2002). Nitrogen uptake and distribution in crops: an agronomical and ecophysiological perspective. *Journal of Experimental Botany*, *53*(370), 789–799.

Hawkesford, M. (2012). The Diversity of Nitrogen Use Efficiency for Wheat Varieties and the Potential for Crop Improvement. *Better Crops, 96*(3), 10–15.

Johnson, A. (2004). Agricultural nutrients and climate change, Crop nutrients and the environment. *Progress Knowledge*, Canada, 202–211.

Klimashevskiy, E.P. (1991). *Genetic aspects of mineral nutrition of plants*. Agropromizdad, Moskva, 25–29.

Kostadinova, S. (2000). Response of winter common wheat (*Triticum aestivum* L.) to the level of nitrogen nutrition, *Ph.D. Thesis*, Sofia.

López-Bellido, R., López-Bellido, L. (2001). Efficiency of nitrogen in wheat under Mediterranean conditions: effect of tillage, crop rotation and N fertilization. *Field Crops Research*, *71*, 31–46.

May, W., Fernandez, M., Holzapfel, C., Lafond, G. (2008). Influence of Phosphorus, Nitrogen, and Potassium Chloride. Placement and Rate on Durum Wheat Yield and Quality. *Agronomy Journal*, *100*(4), 1179.

Mineev, V.G. (2001). *Manual of Agrochemistry*. Academic publisher of Moscow State University, Russia.

Mohammadi, R., and Amri, A. (2009). Analysis of Genotype x Environment Interactions for Grain Yield in Durum Wheat, *Crop Science*, *49*(4), 1177–1186.

Ortiz-Monasterio, J.I., Manske, G.B., Van Ginkel, M. (2001). Nitrogen and phosphorus use efficiency. In: Reynolds, M.P., Ortiz-Monasterio, J.I., McNab, A. (Eds.), *Application of Physiology in Wheat Breeding*. CIMMYT, Mexico, 200–207.

Panayotova, G. (1999). Nutrition of durum wheat (*Tr. durum* Desf.) cultivated with cotton in crop rotation, *Ph.D. Thesis*, Sofia.

Panayotova, G. (2001). Response of Durum Wheat Genotypes to Nitrogenous Fertilizers. *Plant Science, 5-6*, 203–207.

Panayotova, G. (2010). Effect of Soil Fertility and Direct Nitrogen Fertilization on the Durum Wheat Varieties in the Conditions of Central Southern Bulgaria. *Proceedings 12th International Symposium "Materials, Methods & Technologies", 4*(1), 281–293. June 11-15, Sunny Beach, Bulgaria.

Panayotova, G., and Yanev, Sh. (2001). Response of Durum Wheat Genotypes to Nitrogen Fertilization. *Animal Science*, *6*, 109–111.

Panayotova, G., and Gorbanov, S. (1999). Influence of the fertilization on the properties of durum wheat grain and pasta products. *Bulgarian J. of Agric. Science*, *5*, 425–430.

Panayotova, G., and Valkova, N. (2010). Effect of previous and direct nitrogen fertilization on some grain properties of durum wheat varieties. *Proceedings 14th International Eco-Conference® SAFE FOOD*, 22nd-25th September 2010, Novi Sad, Serbia, 131–138.

Rharrabti, Y., Villegasb, D., Royo, C., Martos-Núñeza, V., García del Moral, L. F. (2003). Durum wheat quality in Mediterranean environments: II. Influence of climatic variables and relationships between quality parameters, *Field Crops Research*, *80*(2), 133–140.

Sanjeev, K., Rajender, K., Harber, S. (2000). Influence of time sowing and NP fertilization on grain quality of macaroni wheat (Triticum durum). *Haryana Agricultural University Journal of Research, 32*(1), 31–33.

Sylvester-Bradley, R., and Kindred, D.R. (2009). Analysing nitrogen responses of cereals to prioritize routes to the improvement of nitrogen use efficiency. *Journal of Experimental Botany*, *60*, 1939–1951.

Tomov, T., Rachovski, G., Kostadinova, S., Manolov, I. (2009). *Handbook of Agrochemistry.* Academic publisher of Agricultural University of Plovdiv, Bulgaria.

Uppal, R., Singh, R., Jagrup, S. (2002). Effect of nitrogen levels and time of application on quality of durum wheat. *Crop Improvement*, *VL*(29), 58–64.